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RAILWAY ENGINEERING

MECHANICAL AND ELECTRICAL

BY

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"LIFE AS AN ENGINEER"

"CIVIL AND MECHANICAL ENGINEERING, ETC."

"3,800 MILES ACROSS CANADA"

ETC.

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PREFACE.

The very high appreciation of my books on "Civil and Mechanical Engineering," and "Steamships and their Machinery—from First to Last," by all classes of readers at home and abroad, has encouraged me to prepare another upon "Railway Engineering—Mechanical and Electrical." This treatise is based upon the Author's practice in the Works of the North British Railway Company, Messrs. Denny & Co. and Neilson & Co., of the Clyde, and Laird Brothers, of Birkenhead, &c.; also as a Civil and Mechanical Consulting Engineer since 1873. Its object has been to describe, in a simple, unconventional, interesting, and readable manner, the latest phases of Railway Engineering and its surroundings in all departments.

With the view of obtaining the best and latest information on all points, and especially upon the famous establishments to which special chapters have been devoted, I have had the privilege of being allowed to critically survey these and many other works, and, in addition to this, much valuable matter has been generously supplied by engineers and others throughout the country, and also in the United States and Canada.

Were I, however, to particularise any of these, it would certainly be those whose railway plant, manufacturing, and working operations have been described most fully in detail,

namely:—Messrs. Sharp, Stewart & Co., of Glasgow, and Mr. F. W. Webb, the Chief Mechanical Engineer of the London and North-Western Railway Company. A visit to the works of the former supplied me with material for five chapters on locomotive design and construction; and a still more minute inspection of the vast establishment at Crewe provided me with information upon which to base no less than six chapters on Railway Engineering, so far, at least, as the building and repairing of engine and carriage rolling stock, and the general mechanical working of the whole line, in their most improved and comprehensive forms, are concerned.

For special information regarding the machinery and operative processes connected with railway construction in its multitudinous phases, and also for permission to use illustrations of the same, I am further indebted to the very numerous firms whose favours have been acknowledged in the text.

The primary object of the work has been to select imaginary territory, in which the resources of modern science had to be brought into play, beginning with those of the pioneer order, and ending with those of the most advanced class. As, too, the intention throughout has been to show how the same operations are now conducted in any part of the globe where they may be required, it is hoped that this volume will prove acceptable to many.

J. W. C. H.

30 North John Street,
Liverpool, *April*, 1897.

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CHAPTER I.

OPENING OUT A NEW FIELD FOR ENTERPRISE.

John Smith, Esquire, of London—His Financial Decay and Retirement—A good Invention—"*Never* to have thought of THAT before!"—Again Enriched—His Unique Cruise in the steam yacht *Bengal*—Discovery of a New Island in the Pacific—Return to England—Honours for the Smith Family—Origin of some of the great American Cities—Causes of their marvellous growth—The Mineralogical, Agricultural, and other riches of Baratania—Rush of Nations to the Island—Initial Efforts in Australia of the Past—In Baratania of the Present—Laying the foundation of its Future Prosperity.

IN this treatise, it is our intention to place before the reader the latest phases of Engineering in its general application to the necessities of large communities which require to be worked up to the highest standard of excellence by means of the Railway System. To enable this to be done, let us suppose that an island has been discovered in the Pacific, which is in time to become the scene of operations on a grand scale, and as there are valuable unexplored territories still to be found, the remarks contained in the following pages will, it is hoped, prove acceptable to many.

John Smith, Esquire, of 333 Fenchurch Street, London, was a rich and well-known East India merchant. Strictly speaking, he *had* been prosperous, but financially decayed commerce had gradually reduced his profits, until at last they might have been represented by the letter "*x*" of algebraical significance. When this point was reached,

Mr. Smith handed over his business to his sons, "Mr. John," and "Mr. James," and retired into private life. Not long afterwards he went to Brighton, and while one fine day pensively pondering over the perplexing peculiarities of his late Anglo-Indian associates, he was suddenly arrested by a very practical idea which seemed to have been flashed upon him from the skies in a manner well known to many whose inventions have had a world-wide reputation.

"Dear me!" he exclaimed, "Is it possible that I have *never* thought of THAT before?"

Next day he called upon an engineering friend in the metropolis, and after discussing with him the supposed merits of his invention, it was finally patented in all the civilised countries, and placed in the hands of a good manufacturing firm to develop in every possible way. So ably did the latter execute their part of the business, that not only did they themselves become enriched, but Mr. Smith once more acquired fortune. He now conceived the happy idea of starting on a voyage of discovery with his wife and daughters—Miss Helena Victoria, and Miss Beatrice Frederica—all of whom were charming women.

The desire to travel on new lines irresistibly seized every one of them, the result being that the splendid steam yacht *Bengal* was chartered for a unique cruise, which included visits to places that hardly anyone had ever seen, or read of, or even heard of, and whose names were only to be found in costly atlases. The proposed trip was therefore one to which all looked forward with delight, little imagining that their efforts were so soon to be crowned with the most wonderful success and to open out new avenues of prosperity for every civilised nation.

As Mr. Smith had no nautical knowledge, he engaged

Lieutenant Fairfax, R.N., as his navigating commander. This gentleman was a splendid specimen of a naval officer, courteous, polite, amiable, etc. He was also highly accomplished in various ways, and possessed a large amount of quiet humour, with prodigious powers of conversation on all subjects, especially upon his own marvellous escapes and various other incidents of a remarkable career. As the commander had "been all over the world," Mr. Smith was very fortunate in being able to place the safety of his ship in such excellent hands. The ladies, too, highly approved of his choice.

The day of departure arrived, and with a fair wind and under full sail, the *Bengal* headed for the Nicaragua Canal, as it was the shortest route to the scene of their explorations in the vast island region of the Pacific. Here they had ample opportunities for gratifying their curiosity amidst the marvels and beauties of that wonderful portion of the surface of the globe. After visiting some of the islands and island groups practically unknown to anyone, they started for a cruise in a long stretch of open sea, until one fine morning the look-out reported "land ahead," where no land should have been. Great was the consternation of all when it was discovered that *Philip's Imperial quarto Atlas*, as well as the charts, showed that from 2,500 to 4,000 fathom water existed over the very large area in front of them.

"Can it be possible," thought Captain Fairfax, "that the Americans have overlooked this? or that the *Challenger* has never seen this place? or that *no* one has made the discovery? Perhaps, after all, it is only the result of some volcanic disturbance we have not yet heard of."

Upon approaching the land, its ranges of mountains became clearly visible as the yacht was steered for what

proved to be a magnificent bay, having an inlet leading to a land-locked harbour of great extent. After bringing the ship to anchor, an exploring party started in one of the boats, and to the intense astonishment of all, they soon perceived several people on shore who had apparently come to welcome them, and who, as it afterwards proved, were English residents!

Nearly all the great mysteries of the past have proved capable of natural explanation when people knew how to look for it, and this incident proved no exception to the rule. It was soon discovered that the inhabitants referred to had only six months before formed part of the crew of a ship which had been driven a long way out of her course during a most violent and prolonged storm, until at last she foundered with nearly all on board close to this locality. The survivors had in the meantime become quite attached to their new home, which had spontaneously and most abundantly supplied them with the necessaries of life.

Being so far out of the track of vessels, it was no wonder that the people referred to were left so long to themselves on what proved to be an uninhabited island, but why the navigators of all ages should have missed it is one of those things we cannot comprehend.

After a short but delightfully profitable stay, during which much was learnt concerning this New-found-Land, the Smith family left for England, where the news of the discovery created such intense interest that exploring parties were immediately sent out by the Government to critically examine and report upon what they saw. The latter found out, in course of time, that the new territory was a very large island. A land, indeed, of beautiful hills and mountains, and valleys and plains, of rivers and water-courses; of great fertility, and also possessing a

splendid climate. In short, taken all round, this Isle of "Baratania," as we shall term it, was considered a most valuable acquisition, and one which would prove an admirable outlet for our over-crowded and industrious populations.

When the *Bengal* came home, and the results of her cruise were published, the Smith family were lionised everywhere, especially by the members of the Royal Geographical Society. Mr. Smith shortly became known as "Sir John." The younger daughter ceased to be "Miss Beatrice." "Miss Helena," who during the voyage had made up her mind to change her name, was joyously enabled to do so in St. George's, Hanover Square, by her late officially, but now matrimonially, navigating commander, who, in after years, never ceased to look back upon his trip in the steam yacht *Bengal* as the best he had ever made. Lady Smith was delighted with everything, and now saw, to her own satisfaction, that the success which had so abundantly attended them was primarily due to dreaded disaster, or at least to her husband's failing fortune in the East India business, which had eventually caused him to retire from it. The working staff of the ship were handsomely rewarded for *their* share in the Baratanian enterprise, and with these remarks we drop the curtain on the first act in the play.

The new and greatly shortened ocean route to the East, through the Nicaragua Canal, opened out brightened prospects for some of the steam ship lines, which were still further improved as the resources of Baratania became known, and people began to pour into it. The origin of some of the great cities of the world may help to show how unexpected events, or geographical or other

circumstances, may sometimes determine their locality at the outset. For instance, nearly all the capitals are placed at or near the mouth of navigable rivers, because this is the best position for creating the trade and commerce upon which their prosperity so much depends. The minor cities and towns, on the other hand, owe their creation to a great variety of local causes, sometimes accidental, but chiefly from the presence of one or more native products that introduce and develop special trades or manufactures.

The once magnificent city of Palmyra, for example, was built in the midst of a desert, because its site happened to be a halting place for caravans; and so on in various ways for other places.

Liverpool, 200 years ago, was a mere fishing hamlet, the rapid extension of which into the present city of at least 750,000 inhabitants being due to its naturally excellent position at the mouth of the Mersey; and, secondly, to the enormous trade created by the coal, iron, and general manufacturing industries of the adjacent districts, that were initially stimulated by the inland engineering movements, to be referred to later on.

In America, similar circumstances have produced the same result, but with much greater speed. For instance, San Francisco has advanced by leaps and bounds from a population of 34,000 in 1850, to at least 400,000 in 1890, whilst Chicago has gone through its own wonderful performances as follows:—In the year 1840, her population was 4,479; in 1850, 29,963; in 1860, 109,206; in 1870, 306,605; in 1880, fully 500,000; and whilst, between the latter year and 1890, Buffalo and other eight cities in the States, including New York, had additions of from 100,000 to 309,000, Chicago went ahead of them all with its unparalleled increase of 596,665 during the above period

of only ten years; thus clearly indicating the extraordinary rapidity with which a combination of favourable circumstances may enable modern communities to extend.

These, and many other instances might be adduced to show how the growth and prosperity of cities and towns is due partly to local causes, and partly to their *systems of inter-communication* with each other and with the sea. Hence, we may reasonably assume that what has been successfully performed in the past may be similarly accomplished in Baratania as its resources become developed.

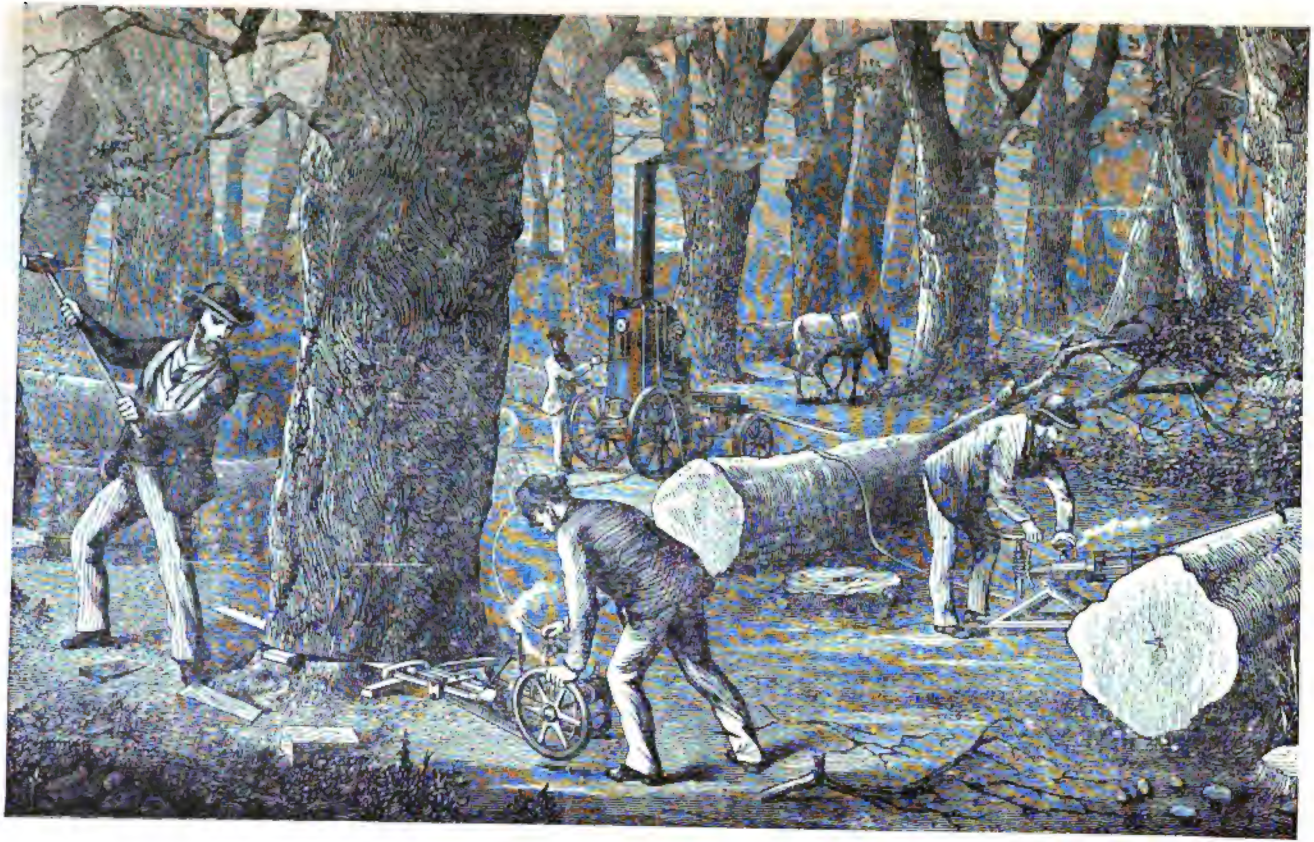
A careful preliminary survey has indicated its excellent mineralogical, agricultural, and other properties, sufficient in the first instance to point out a few of the best localities for future operations. It has also shown that the island is capable in time of having an excellent cross-country traffic. The harbour, also, to which we have referred, will form a very good point of communication with the outer world and prove a splendid seaport as the commerce of the country becomes enlarged.

In the course of their peregrinations, the Government engineers ascertained that coal and iron could be obtained in large quantities, and that some of the plains were admirably adapted for farming pursuits, whilst other parts were abundantly wooded, the whole country, indeed, offering the greatest inducements to prospective residents. When these facts became known throughout the world, a great rush was made to the colony by people anxious to improve their condition on new lines, and with free scope for talent and industry. Hence, in a very short time, large and small tracts of land were appropriated for farming purposes, the new arrivals having at once to construct for themselves a number of log huts as temporary residences.

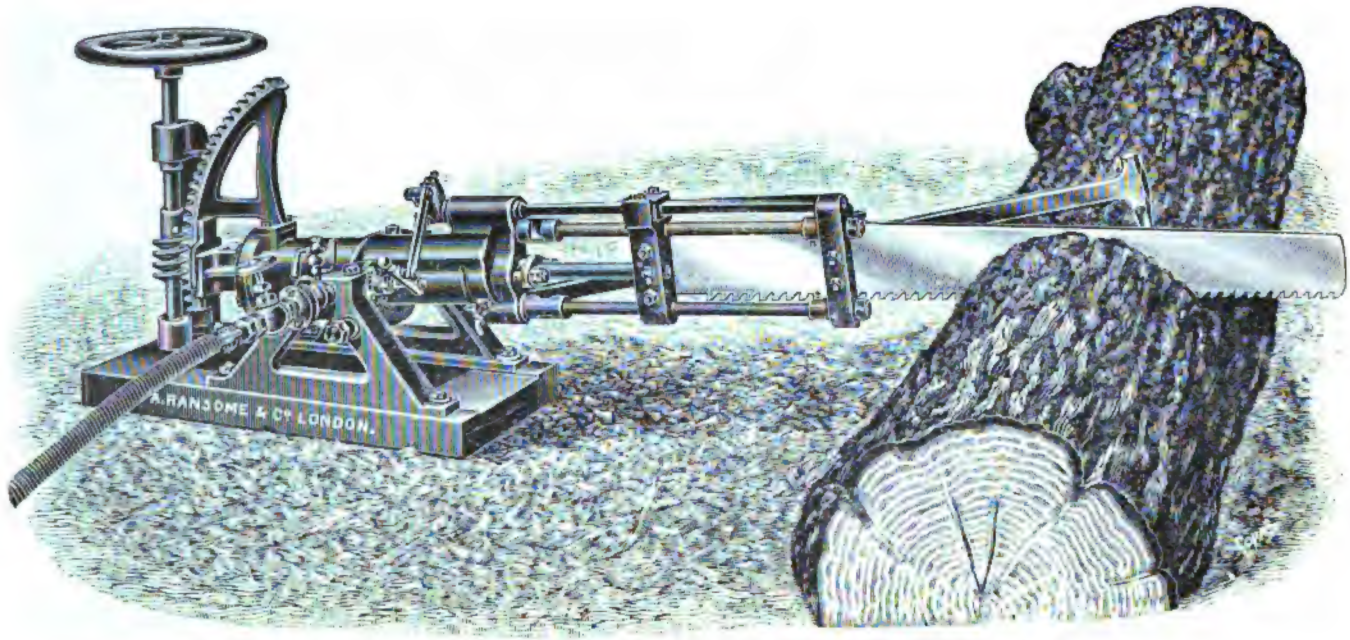
"When I was a lad," my father gave up legal practice for a time, on account of his health, and commenced farming near Sydney. I fairly remember the timber-cutting operations of those days. Firstly, the trees were felled with the axe alone, and then cut into suitable lengths with a two-handled cross cut saw. After that they were split into paddock rails, posts, etc., by means of large iron wedges. The more *finished* class of timber for house-building, however, was worked by pit-saw hands, whose performances were somewhat similar in principle to those of the log sawing machines of to-day.

Shingles, for roofing purposes, were wedge-split out of short segments of trees in the rough state, and so on all through. The grand leading feature at every point being the extremely laborious, slow, and primitive methods employed from first to last, which, at that time, could not be avoided. A knowledge of hand-tool working in iron is often useful in distant places, but a fair experience of carpentery and joinery is indispensable, as these arts are so extensively employed abroad in every kind of construction, and especially for pioneer purposes. Hence, a few remarks upon the machinery which aids hand labour, and rapidly prepares the rough timber, will no doubt be useful, especially when it is universally applicable to railway as well as to other work.

We have said that in Australia tree-felling was accomplished by the axe alone; with the object, therefore, of superseding this most barbarous custom, Messrs. A. Ransome & Co. some years ago introduced their *Steam Tree Feller* and *Log Cross-cut Saw*, shown in the adjacent views. It will be noted that in the Forest Scene the apparatus is shown in operation as close to the ground as possible, thus saving some of the best part of the tree, which, however,



TREE FELLING OPERATIONS IN A FOREST.



TREE CROSS CUT SAWING MACHINE.

may be easily cut level with the ground if all surface obstructions have been removed.

As this simple little machine, suited for trees up to four feet diameter, weighs less than 450 pounds, it is capable of easy transport and rapid fixing in any position, either on level or on sloping ground. The saw is actuated by means of a long-stroke steam cylinder, to whose piston-rod it is attached, whilst the swivelling and feeding motions are controlled by the hand wheel and toothed quadrant shown in the view.

When used for cross-cutting, the machine is placed in a triangular frame, as illustrated in detail, and securely fixed to the tree by means of a hinged dog-hook, the Plate of, let us suppose, a forest scene in Baratania, showing very clearly the separate operations of felling and log cutting. The man with the sledge hammer, for instance, is wedging up the tree to prevent its weight from retarding the saw. The other is regulating the feed, while, at the same time, the motive power is supplied by the adjacent portable steam boiler, through flexible pipes, to this machine and also to the neighbouring one. The speed with which these operations are performed may be gathered from the fact that eight trees, of say 30" diameter, may be cut down with ease in one hour, inclusive of time occupied in fixing and removing the machinery. It may be added that the whole picture shows at a glance the most improved initial operations upon which the whole fabric of economical timber cutting is now based.

The above machines have been extensively used in America and the Colonies upon trees of all sizes, their accompanying steam boilers being fitted for burning waste wood, and capable of easy transportation.

In countries where the state of the ground permits its

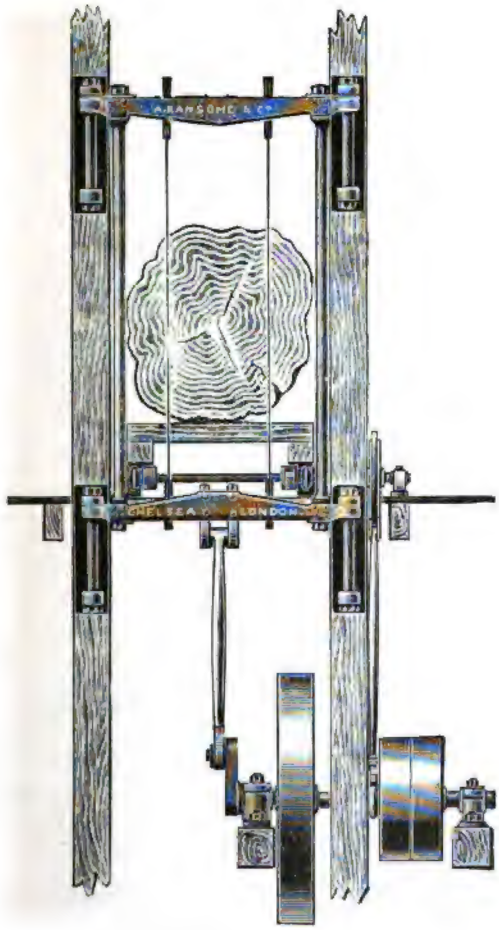
use, a tree-feller, mounted on wheels, is very useful, particularly when of large size. A *special* boiler may also be dispensed with, as the boiler of any portable engine within reach can be used for supplying steam to one or more machines if desired. In isolated spots, however, where operations are only on a very limited scale, the good old primitive axe and saw must ever reign supreme in the case of those whose backwood or bush life is of the rudest character.

For lifting or adjusting purposes, a very simple *Hydraulic Screw Jack* forms a most useful portion of the tree-felling plant, but for handy picking up and easy transport of large logs, nothing can exceed the well-known "Janker," as it is usually termed, consisting of two wheels and an axle. The timber is slung immediately under the axle, which is bent, the pole of the carriage acting as a powerful lifting lever. The limit to the size of log these vehicles will take in depends upon the curvature of the axle and the diameter of the wheels, which generally ranges from five to six feet.

After the trees have been cut down, as illustrated in the Forest Scene, the next operations include the sawing of the former into squared logs, planks, etc., as may be required. And although the pit saw hands of new localities have to perform this in the barbarous style of early days, there is no necessity for doing so when the simple and inexpensive *Vertical Sawing Machine*, by Messrs. Ransome, shown on the next page, can be utilised for the purpose.

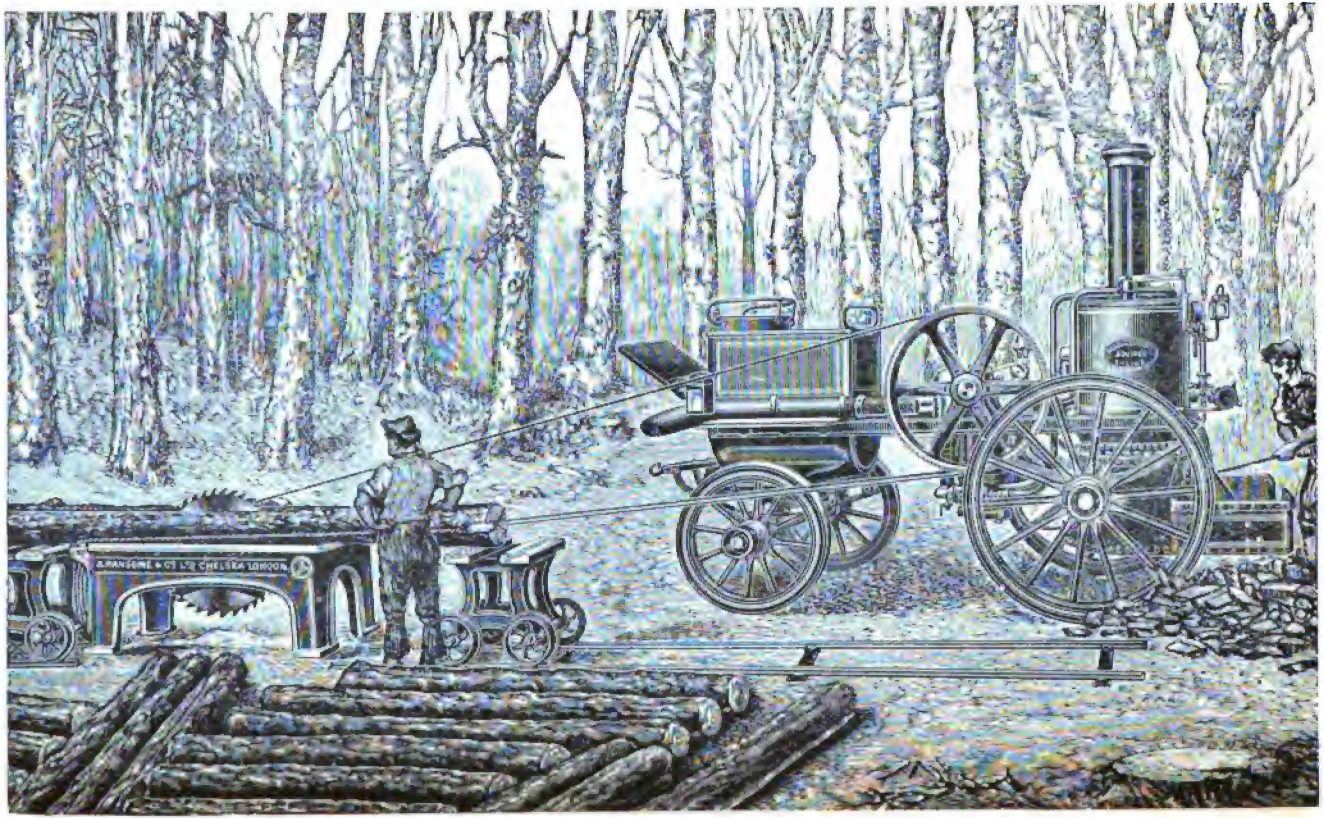
This machine may be used with great advantage in outlying places, as it embodies, in primitive fashion, the main principles of some of the costliest productions. Its special advantages consist of metal work in small detach-

able pieces, capable of transport on the backs of mules or horses over a difficult country, the timber framing being made on the spot if required, whilst, on the other hand,



VERTICAL SAWING MACHINE.

the driving power may be obtained from any available source to work two or more saws at one time, according to circumstances. The whole design clearly illustrates a



SAW BENCH WORK IN THE FOREST.

principle that permeates machinery of every kind that is to be conveyed to isolated spots abroad. Another feature of the plan is the extreme simplicity of its details, so that unskilled colonials may have little trouble in taking them to pieces for removal or repair.

One of the most useful of the forestry machines is the *Self-Acting Saw Bench*, by the above firm, adjacently illustrated with all its connections and driving engine, the former of which can be used for either timber or deals. For such purposes it is the essence of simplicity, as all spur gear is dispensed with owing to the difficulty of repairing damages in some localities. In this case, therefore, a drag rope or chain is coiled round a large drum, driven at different feed velocities from the saw spindle, and by means of which an iron carriage placed at each end can be worked. For various minor operations the machine is equally convenient, as the fence is adjustable to any angle for bevelled work, or it may be easily removed and thus leave the table free for cross-cutting. The motor is one of Messrs. Merryweather's famous coal or wood supplied Fire engines, which are extensively used for such purposes, as they also act not only as a stand-by in case of fire, but are useful for driving pumps, corn mills, thrashing machines, and electric light installations, as well as sawing machines, which occupation may be more or less of a temporary nature.

We have, at the outset, introduced the reader only to a few of the most rudimentary or pioneer appliances for opening out a new territory and laying the foundations of its future success. The application of these machines, and the advantages to be derived by their use, will be described as we proceed. At the same time, the other branches of Engineering that help to increase the pros-

perity of the inhabitants will be incidentally brought in as the plan of operations becomes extended. These few remarks, it is hoped, will indicate the lines upon which we intend to run the following chapters, whilst endeavouring to show how the resources of modern engineering may be utilised most effectually. We shall also have the pleasure of illustrating the manner in which commerce and engineering aid each other in developing to the utmost the resources, not only of our imaginary Island of Baratania, but those of *real* islands, or countries in any part of the globe.

CHAPTER II.

PIONEER MOVEMENTS ON NEW TERRITORY.

Life in New and Old Countries—People who succeed in the Former—Discovery of a valuable District in Baratania—Grand Opening for Settlers—New Westward route to the Far East—New Life for the Liners—Internal Communications of a Country—As they were in the Past—As they are Now—Main Features of Land Surveying—Application of Geometry—Levelling—Errors in Levelling and their Results—Surveying Instruments—Preparation of general Plans—Simple methods of Copying, Enlarging, or Reducing Drawings—Finishing Touches.

BEFORE entering upon practical science questions connected with the management of our new-found-land, let us note a few of its social aspects. It is, we should think, pretty well known that life in a new country is very different indeed from what it is in the old and civilised ones, since, in the former, everything is rude and primitive in the highest degree. For instance, the bush, or prairie, or backwood residences of the settlers are as rough as they possibly can be, the walls being of logs that too often form a lodgment for snow or rain, and give easy access to a freezing atmosphere. The sides of boxes mounted on logs serve as tables, while the same boxes may at other times become seats, or beds, as required.

The internal decorations will probably consist of a number of choice pictures from the *Illustrated London News*,

or *The Graphic*, etc., pasted on the walls. The floor may be the ground itself, or, by way of luxury, one whose rough planks have shrunk so much that stray half-crowns will easily find a resting place beneath them. Home-made candles will be used for lighting purposes. Water may be obtained from a well, or a muddy pond, or, during dry weather, in barrels from a partially exhausted river some miles distant. Plates, cups, etc., will be of tin for durability, and provisions of all kinds, except native produce, will have to be laboriously obtained, in large quantities at a time, from a town perhaps fifty or sixty miles away.

All the usual travelling will be done on foot, or on horse-back; in short, life at first will be pretty much as we have described it, with all its discomforts and privations, until things have righted themselves, and a clear path opened out. When this is done, the refined ideas of the home country will begin to show themselves in various ways, and thus, the desert may in time become a garden.

The people who will be able to accomplish this will certainly not be those who are always *waiting* for "something good to turn up," nor those whose chief "appointments" in a new land would be as hewers of wood and drawers of water, with food only as pay. There, young lady telegraphists and typewriters, and clerks wanting situations, will not find a resting place for the soles of their feet, neither will decayed idlers of fashion, unless they can make up their minds to rough it in some form or other.

Who, then, are the bees that get all the honey? Well, we should say all timber working hands, chiefly carpenters and joiners, also agricultural people of all ranks, and those of the artizan class generally, exclusive of masons and bricklayers. Those, however, best suited for attaining the

prosperity that is denied them at home are, perhaps, the ambitious younger sons of the aristocracy and gentry, when actuated by a desire to work their own way to success. Such, indeed, are they who in after years may become possessors of handsome houses, with gardens, orchards, and grain-bearing paddocks attached, also flocks and herds in abundance, or have returned to their former professions under greatly improved conditions, unless bank failures, or long droughts, or equally disastrous floods, have injured their prospects.

Amongst the various discoveries made by the surveyors, aided by the original shipwrecked inhabitants, has been a large tract of country about thirty miles inland, which, in their opinion, will form a most valuable agricultural district, and all the more so as it is intersected by the broad navigable river "Derwent"—let us call it—that enters the harbour of "Deephaven," as we shall appropriately term our future seaport; thus forming with the interior a direct communication of which the new settlers are rapidly availing themselves.

When my roving coloured brethren and sisters of Australia visited our locality, they used to build their camps by cutting saplings to suitable lengths of three in a set, the lower ends of which were fixed in the ground, whilst their upper extremities were fastened together. When the hollow triangle thus formed was covered with sheets of thick bark, peeled from the adjacent gum trees, the residence was complete, the fire for cooking opossums, bandicoots, etc., in the most primitive fashion, being made on the ground just outside the entrance.

A step in advance of this is the log hut of pine-growing regions, where the mast-like trees are cut to even lengths,

then notched at the ends somewhat in half-lap fashion, and finally built up into houses with the aid of the most rudimentary carpentry. Another step is to be found in the Australian houses, whose foundations are of logs laid on the ground, to which upright pieces are secured. When the latter are planked in the "weather board" style, the floors properly laid, and the interior lathed, plastered, and touched up with a view to comfort and elegance, these habitations may become very desirable residences, especially in districts where timber is the most convenient building material, and this, as the Scandinavians can abundantly testify, may be employed with great effect, according to the taste and skill of the proprietors.

Although the Island of Baratania is mineralogically rich, the pursuit of agriculture will primarily occupy the attention of the settlers, who are arriving in rapidly increasing numbers, thus incidentally helping to originate the future city of Bathurst, at a spot on the banks of the Derwent, 32 miles from Deephaven, which even now is becoming a scene of great activity.

As things are thus progressing, we begin to see what a splendid opening this new territory will be to multitudes as the days go by. Talented engineers, whose hopes of even moderate success have been grievously damped in the old countries, will here find full scope for their energies, so also will people of all ranks who cannot attain the prosperity they deserve. In addition to these may be mentioned the unfortunates who have been advised to emigrate to other lands, but find, after all, that they are no better off than before, and so on—men and women alike. All these, and many more besides, will soon make this lovely Pacific region the home of the happy, and the abode of peace and plenty.

In a very short time, the S.S. *Clan Gordon* and *Karamania* arrive from Liverpool with crowds of passengers and full cargoes of stores, implements, and odds and ends of every description. This event created profound interest all over the locality, as one might have expected, and no sooner were the settlers landed than they at once proceeded, in little wood-fired steamboats, to their new home at Bathurst, where house building, as previously described, and preparations for farming were at once commenced.

When the above ships cleared out of the harbour their places were occupied by others, and so rapidly did the traffic increase that in a short time timber jetty accommodation became a necessity, as well as an extension of the river service, to which we have referred. Whilst for a time these and other events connected with Baratanian progress remain unnoticed, let us consider various things that will aid that progress in other ways.

There is, perhaps, hardly anything that has had a greater effect upon the prosperity of countries than their *Internal Communications*, either by road, rail, or water, separately or collectively, as the history of England will abundantly testify. Nowhere has this been more conspicuously visible than in the Manchester and Liverpool districts, whose rapid advances in recent times may point a moral and adorn a tale, and help to throw light upon future proceedings in our new territory as its resources become developed.

In the year 1760, the roads around and between the above cities were so wretched as to become frequently impassable, the result being that the trade of Manchester, small as it was, found its way on pack-horses to the Severn, down which it was floated to Bristol. The Duke of Bridgewater, who at that time ardently studied engine-

ering under Brindley, noted this, and proposed to connect the two towns by means of a canal, and soon afterwards began its construction. Previous to this, all attempts in canal engineering had only been to widen existing ditches and small streams, whereas the canal just mentioned was cut through solid ground, involving careful surveys, and difficult and costly works, such as bridges, viaducts, etc.

As Manchester had thus a direct outlet to the sea, its trade went up with a bound. Lancashire manufacturers flourished to an enormous extent, and the commerce of Liverpool was similarly benefited. The Bridgewater Canal ultimately brought in a revenue of £100,000 a year to its proprietors, who became so exacting as to cause a movement to be initiated which, from a small beginning, was the means of revolutionising the business of the whole world.

Owing to the frequent blocking of the Canal through excess of traffic on the one hand, and its ice-bound condition in winter on the other hand, goods were sometimes most inconveniently delayed in transit. With the object of remedying this unendurable evil, the Liverpool merchants resolved that George Stephenson should be applied to for advice on the subject. Having gained useful experience on the Stockton and Darlington, and previous colliery lines, he immediately proposed a *railway*, the very idea of which greatly dissatisfied the county of Lancaster. The landed proprietors, the little villages and towns, and all the country houses declared that they would not have their territory desecrated by an innovation which was sure to bring with it many serious evils. The most strenuous opposition, however, came from the Duke of Bridgewater's people, who waged a war of extermination against *all* railways; even the Duke of Wellington disapproved of them.

The surveyors had a rough time of it wherever they went, and by the merest chance the scheme was passed by Parliament. The line was accordingly commenced, and thus began the Liverpool and Manchester Railway, which, with Stephenson as engineer-in-chief, was successfully opened on September 15th, 1830, and, through the fabulous prosperity that almost at once attended it, set everyone on fire for similar undertakings.

Some idea of the extent of the speculative mania which existed at this time may be gathered from the fact that, from 1823 to 1844, the total cost of completed lines had been £70,681,000. Those in progress in the latter year were estimated at £67,360,000, but in the same year there were 1,428 projected railways, with an estimated capital of £701,243,000, many of which were only gigantic frauds.

At this period, lawyers and engineers quickly made large fortunes, the former received immense fees, not only for their professional labours, but also for doing nothing, or at least for withholding their services from others who wished them. The engineers had a regal time of it; but they were worked like slaves, and, in many cases, were not in bed for a week at a time in their anxiety to finish the parliamentary plans for a new line by a certain day, or they would not have been received.

Holding, as they did, the key of the position, they were bullied unmercifully when in the witness box by opposing counsel, under, over, and through every possible and impossible phase of the question, and required, not only to be masters of their art, but masters of strategy as well, to enable them to carry their point. They had to know how to advance their crushing statements under fire from the enemy's batteries, and when to retire behind their defences. If the scientific witness were too closely pressed, he had

one safe retreat at all times, into which none could follow him ; he would retire into a thicket of algebra, from which he could shoot forth a furious volley of arguments relating to sines and co-sines, tangents and co-tangents, optical squares and chord angles, zenith distances, equatorial axes, the curvature of the surface of a spherical triangle in relation to the ellipticity of the earth, and so on, until his persecutors were glad enough to let him alone.

What magnificent opportunities, too, the Q.C. of the period had for the display of forensic genius! Under his elequence one would have imagined that raising embankments, crossing rivers, and penetrating mountains, was quite an elegant recreation. "The talent of the engineer would easily overcome every obstacle; in short," he continued, "there never was a line so advantageous in every respect, nor one which would prove so remunerative to the shareholders." The opposing counsel, however, did not quite entertain the same views. He, too, could give a brilliant oration, but concluded *his* remarks by observing that "he had the greatest confidence in the ability of his learned friend, who had spoken so truly on many points, but opinions differ, and he had every reason to believe, from what their engineer had informed them, that although the tunnels, bridges, and embankments could no doubt be successfully executed, it would be at such an enormous cost as to entail heavy loss, if not ruin, on all concerned in the undertaking, therefore he, for one, would not sanction the scheme." In this manner railways, in early days, were lost or won—as indeed they may be still.

As the general prosperity of roads, canals, and railways primarily depends upon the skill of the surveyor, we may here make a few remarks upon the *Science of Land Surveying*, before going any further. The origin of this all

important branch of engineering has been attributed to the annual inundation of the Nile, the deposit from which destroyed the land-marks, hence some accurate method of ascertaining the boundaries of various properties became necessary. This object was carried out most effectually by Euclid, whose reasoning forms the basis of a surveyor's education, which includes an intimate knowledge of geometry, algebra, logarithms, mensuration, etc.

In its broadest sense, land surveying is the art of preparing maps and plans of a country, or a large or small portion of a country, an empire or a state, showing its mountains and valleys, roads, rivers, waterways, fields, woods, boundary lines, houses, etc., as required. These plans may be drawn to any convenient scale, according to the size of the original, and also the proposed drawing or number of drawings in the set. Hence, if only the outline of a small piece of land is required on one sheet the scale may be 10, 20, or 30 feet to one inch, but if a whole country has to be delineated on numerous plans, the scales may range from 1 to 6, or even to 25 inches to one mile.

The one inch scale is employed for the smaller ordnance maps, and is well adapted for exploration purposes, whilst the 4 inch scale is the smallest allowed by Parliament for the deposited plans of proposed works, the 6 inch scale being chiefly used for the larger maps of Great Britain and Ireland. The last named is the most convenient for showing buildings, roads, and other important objects distinctly over a considerable area, and with sufficient accuracy for engineering purposes, for the preparation of parliamentary plans and preliminary estimates. Many other scales are used for enlarged plans of buildings, but those of 10, 20, or 30 feet to one inch, mentioned above, are very useful for special purposes.

The *vertical* scales, or those for heights and depths of 20, 30, 40, and 100, etc., feet to an inch, when used in combination with some of the foregoing, are termed "exaggerated" scales, as those of the natural size would not show distinctly enough the elevations and depressions, as they are so small when compared with horizontal measurements. These are shown in a very marked manner in some of the plans that are brought before the public from time to time in various publications.

Our earliest efforts in engineering drawing consisted in measuring with compasses all the parts of an original plan, which was thus exactly copied. In land surveying however, the country itself forms the original, and this has to be similarly treated by means of chain measurements that are very carefully entered in the "field book," before being transferred to paper by suitable scales. As these measurements cannot be marked upon a drawing when they are taken, the field book notes, sketches, and dimensions, must be entered first, and this operation may be prolonged for various periods according to the nature of the case. It is, therefore, of the utmost consequence that all the above data necessary for producing an accurate survey should be kept for reference in a systematic manner to avoid confusion.

The three main features of land surveying are: the methods of measuring distances on the ground; the manner of recording them for future reference; and the art of plotting the dimensions upon plans. To these may be added the most correct means of calculating irregular areas on a large scale. As the two feet rule is to the mechanical engineer, so is the *Chain* to the surveyor, those most used in England being Gunter's 66 feet chain, and the 100 feet chain. The advantages of the former are that its length is exactly *one-eightieth of a mile*, and that its square is

one-tenth of an acre. The latter, however, is very useful for minor operations where measurements in feet and inches are most desirable. Gunter's chain, on the other hand, may be employed by itself, or in connection with the theodolite and other instruments for measuring angles, but where the measurement of counties, kingdoms, maritime work, and inaccessible distances are concerned, trigonometry becomes invaluable, aided by the theodolite and logarithmic tables.

Geometry, or the art of measuring the earth, is divided into two parts—theoretical and practical, in both of which triangles form the basis, hence the area of a polygon may be found by dividing it into triangles, calculating each separately, and then adding the results together. The theory of triangles, therefore, is the hinge upon which geometrical knowledge may be said to turn, and owing to the fact that a three sided figure is half the area of a parallelogram standing upon the same base and having the same altitude, it becomes in this respect alone extremely useful.

To put it more clearly, suppose, for example, that two parallel lines 20 feet apart were unlimitedly extended, and that upon a 20 feet segment of one of them an infinite number of triangles were drawn between the above, each one differing from its predecessor in form until countless millions had been thus delineated, the curious fact would remain that every one of these triangles would be *exactly* equal in area to the original figure, and to each other. All rhomboidal figures on the same base and between the same parallels as above would give similar results, and further, the lines forming their sides, as well as those of the triangles, illustrate the paradoxical truth that lines may be made to approach each other for ever but without meeting.

Owing also to the fact that in any right angled triangle the square of the hypothenuse is equal to the sum of the squares of the other two sides, its length is consequently equal to the square root of this number. The length of each of the other sides being found in the usual style by deducting the square of either of them from the hypothenuse squared, and then taking the square root.

Amongst the numerous valuable properties of triangles taken by themselves and in conjunction with other figures, to which no reference need be made, we have in the above examples only indicated the manner in which these properties can be practically utilised by the engineer in the science of land surveying, where they have proved absolutely indispensable.

The application of the triangulation system on a small scale may be thus described. Take, for instance, a field in the form of a trapezium, the area of which we wish to know in square yards. The measurement of the sides and angles, and also the diagonals, enables its outline to be drawn correctly on paper, one diagonal alone changing the figure into two triangles whose common base is, say, 500 yards, whilst their vertical heights are 200, and 100 yards. Each triangle may now be calculated separately as follows;—

$$500 \times 200 = 100{,}000 \div 2 = 50{,}000.$$

$$500 \times 100 = 50{,}000 \div 2 = 25{,}000.$$

the sum of which is 75,000 square yards.

If the sides are undulating, a sufficient number of offset measurements must be taken by a long staff, tape line, or otherwise, and the calculated areas of their enclosed spaces added to, or deducted from, 75,000 to obtain the true result. When very irregular figures are concerned, their areas may be mechanically and rapidly determined by

means of a *Planimeter*. This instrument is so constructed that while one end rests on a table, the other end carries a pointer which can be moved in any direction over the outline of a surface, and thus enable the delicate mechanism of the machine to record the desired area, which may be correct enough for many purposes.

In small surveys *Levelling* forms only a small portion of the work, but in great undertakings it is very extensively employed. Accuracy in this respect is of the highest importance, as the records of the past have abundantly proved, not only regarding the greatly increased cost of construction through errors that should have been avoided, but even in the very possibility of a great scheme. The proposed route of the Suez Canal, for instance, was surveyed by French engineers fully 75 years ago, and according to their calculations the difference of level between the Mediterranean and the Red Sea was at least 33 feet. Had this been taken as correct, Robert Stephenson would have altered his opinion regarding this scheme which he subsequently reported upon, but before doing so he made his own survey, and thus found the level of both seas practically the same.

Surveying Instruments are now so perfect that, in the hands of careful practitioners, the most astonishing accuracy is sometimes attained, even with a long series of levels where the slightest error frequently repeated may prove disastrous. This, however, is partially due to an admirable system of independent checks which enable incorrect measurements to be rectified, just as in other branches of engineering.

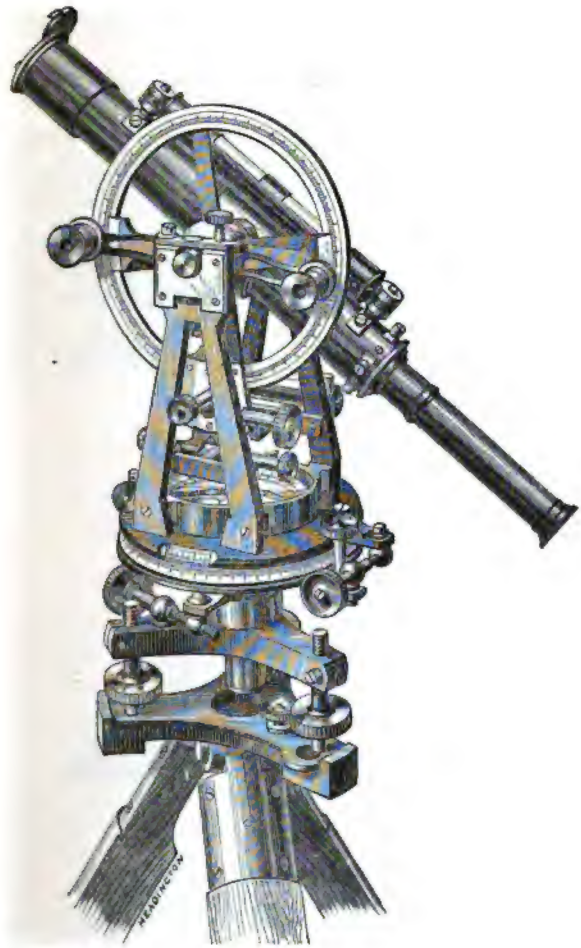
For surveying purposes generally, the *Theodolite* holds the highest rank, since by its use all horizontal and vertical angles can be measured. Hence, when the lengths

of two sides of a triangle and the angle opposite either of them is known, or when two angles and one side are given, measurements of perhaps inaccessible spots, or the values of the remaining angles can be found by trigonometry. This is due to the fact that the sum of the interior angles of every triangle is equal to two right angles, or 180°, hence, when two of them are given, the third can easily be found by deducting them from 180°.

The instrument referred to may be practically understood from the annexed view, which represents one of Messrs. Chadburn & Son's Transit Theodolites, whose structure varies considerably, although their essential parts remain pretty much the same as a rule. The usual material is brass, but the graduated ring of each of the circles is of silver. The telescope, with its spirit-level, and also the other details, hardly require explanation, but we may here point out the beautiful and invaluable feature of the tripod arrangement, which finds a solid bearing wherever it may be placed. This property is taken advantage of, not only in the wooden supports of the instrument, but also in the milled set screws for adjusting it. The Transit Theodolite has the additional advantage of having a complete vertical circle, which, as with the horizontal circle, is divided so clearly that angles can be very accurately measured. It also possesses other useful qualities, and as every movement for ensuring exactness has been fully provided for, lines may be considerably prolonged with perfect safety.

For ordinary purposes, the *New Entire Level* by the above firm, illustrated on page 32, is used in preference to the theodolite on account of its simplicity, compactness, and also the ease with which it may be kept in good condition.

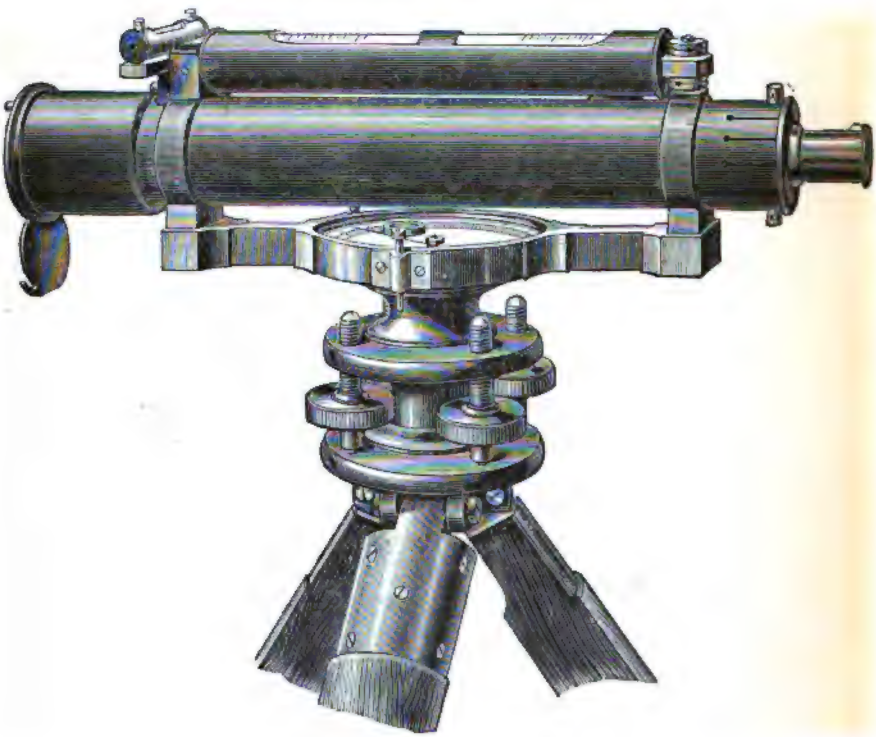
The *Preparation of Plans* is of great importance, so much having to be accurately shown to small scales. As



TRANSIT THEODOLITE.

damp-stretched sheets shrink a little after being cut off a board, the scale should be drawn upon them to pre-

vent the measurements from becoming vitiated, as they would be to some extent if separate scales were used. Where minute accuracy in details is not required, the *Plane Table* becomes useful, since by its aid the plan of a field or



NEW ENTIRE LEVEL.

an estate can be outlined on the ground in such a manner as to determine the principal points, from which the plan may be easily filled up and its area calculated. This apparatus is simply a drawing-board mounted on a tripod,

and capable of horizontal revolution and adjustment by means of set screws. Amongst its accessories are a compass, spirit level, and an index or flat ruler having an upright sight at each end, all of which greatly facilitate operations.

The merely artistic part of the proceedings is of a conventional nature, and this includes the delineation of fences, hedges, stone walls, palings, etc., which are made distinguishable from each other by different methods of treatment, just as the mechanical engineer indicates the various materials in a drawing by suitable flat tints, or by sectionings in lines or colours. Hence, we find that in a survey plan, boundary lines of parishes, counties, etc., are shown in dot and dash style; roads may be coloured with burnt sienna; sheets of water light blue; streams or rivers darker blue; new buildings crimson lake, and old ones neutral tint. Railways are shown by two parallel lines drawn by a double pen, and canals are treated as if they were rivers, but indicate their nature by means of *regular* outlines, while trees are shown sketchily in plan, and painted green.

Even the superficial nature of the land may be indicated by various flat tints that exhibit at a glance whether it is pasture land, marsh, heath, and so on. For engineering projects, however, each portion of property delineated is numerically recorded in a book, and otherwise noted for reference.

When copies have to be made of drawings, the leading points of the latter may be pricked through to the blank sheet beneath them, and then pencilled in. Or, if the original is a tracing, every line can be reproduced at once by means of transfer paper, and inked in without any more trouble. If, on the other hand, a plan has to be enlarged

or reduced by mechanical methods, the *Pantograph* and *Eidograph* may be very usefully employed, but as these instruments are too expensive for only occasional application, simpler methods have to be adopted, such, for instance, as the use of proportional compasses, etc. The most convenient method of all, however, is the square system, so well known in connection with directory plans of cities, which may be thus applied to surveys:—

Divide the original drawing into a net-work of, say, full-size half-inch squares, marked on the two sides with numbers, and on the top and bottom with letters. If a *tracing* is used, the dividing lines may be in *red* for distinctness, and if the new plan is to be of double scale then its squares should be one inch. Having thus prepared both sheets, the work of enlarging the original is very simply performed by means of ordinary dividers and by hand-sketching.

Large printed titles can also be put in very simply and accurately, as the space for, say, one inch deep lettering may be divided longitudinally by lines into five equal spaces, and vertically by lines the same distance apart, as far as may be required. When this is done, the letters may be shown in pencil with great ease, and when inked-in and painted have a handsome appearance. Minor printing may be executed in a remarkably simple rustic style, every movement of the pen being a finished one, thus saving much time, and producing greater effect than the laborious systems so often employed.

CHAPTER III.

PLOTTING OUT THE DEEPHAVEN AND BATHURST RAILWAY.

Great Prosperity of Baratania—Necessity for a Standard Railway—"The Eminent Engineer" on the Scene—Preliminary Considerations—Leading Features of a Railway Undertaking—General Exploration of Country—Marking out the Line—Detailed Plans—Estimating the Cost—"Allowances" for everything—Mr. Brassey as a Railway Constructor—His Gigantic Undertakings—Winning Fame and Fortune—Cutting the "First Sod" of Baratanian Line—How the Governor and his Lady "Bossed the Show"—Canadian Pacific Railway—Explorations and Surveys—Character of the Country—Rapid Construction—Enormous Development of Traffic—Engineering Features of the Line.

THE early history of railways abounds with much of a romantic, tragic, and even of an amusing nature, hedged about as they often were with difficulties to the right of them, obstacles to the left of them, and an agglutinated conglomeration of evils before and behind them, chiefly owing to the prejudices of the people over whose territories the proposed iron roads were to run, of which the previously mentioned Liverpool and Manchester line formed a very good example.

Let us now suppose that the inhabitants of our Island of Baratania have prospered amazingly in all their undertakings, that their towns and villages have greatly expanded, and that the light railways which followed the pioneer portable lines are to be supplemented in the near future by one of the standard gauge, between the rapidly

growing towns of Deephaven and Bathurst—a distance of 40 miles. A diversity of opinion has existed on these points, some maintaining that a 3′ 6″ gauge would be quite sufficient for the purpose, whilst others considered that a 4′ 8½″ gauge line would be better, on account of the brisk traffic already waiting for it, not to mention the probability of great centres of industry springing up at various points along or near its route, at places which have been indicated by the surveyors.

So clearly apparent had these facts become, that Sir Julius Greville, one of the eminent railway engineers of London, was requested to survey and report upon the undertaking, and plan the best means of economically rendering it most useful to the greatest number of people. This, Sir Julius had done with great clearness, and with that highly accomplished practical reasoning which had made all his projects very successful.

It may, perhaps, be well here to state that before the route of a proposed line can be decided upon from a *traffic* point of view, the following considerations, amongst others, have to be taken into account:—

(1.) The relative importance of the various towns and villages which lie, or may lie along its course, and the traffic that may be expected from them.

(2.) The character and resources of the district, whether agricultural, commercial, or manufacturing.

(3.) The number and nature of the population at various points, and all other useful statistical facts that may be collected from the most trustworthy records.

If now, on a large map, a pencil line is drawn from one terminus through the most suitable localities to the other

terminus, a fair preliminary idea of the direction of the railway may be obtained. Formerly, people did not much care for some of the intermediate towns, if they could thus obtain a more direct route between the termini, as they trusted to future branch lines from the former coming to their aid. Even, however, after all these have been allowed for, the engineering peculiarities of the case may require many deviations from the desired course for the sake of economy in construction, if the country is a mountainous and difficult one.

The obstacles which arise from this cause alone are sometimes of a serious nature, the engineer's aim being to cross rivers at the most convenient spots, while hills and mountains have to be skirted, or tunnelled, or passed over by means of a series of more or less steep inclines. All places where land is expensive have to be avoided as much as possible, and a general estimate formed of cuttings and embankments, so that they may balance each other as closely as possible, and thus enable the latter to be constructed out of the excavated material from the former. During the progress of an extended survey, all these, and numerous other features are made clearly discernible, the usual system of operations being as follows :—

A General Exploration of the country is made by the engineer with the view of ascertaining, in all round fashion, the facilities obtainable for the proposed undertaking, and also for approximately determining its best course or direction. During this preliminary process, the geological nature of the country will be carefully studied, and also the sources from which various constructive materials may be obtained. In all these movements the engineer will be greatly helped by large scale maps of the district, and by the taking of flying levels, which are usefully employed for

ascertaining the elevations of isolated spots of primary importance, affecting the practicability, estimated cost of the line, and other leading points.

Having thus outlined his railway, the engineer proceeds to make a more exact selection of its site by means of *Preliminary Trial Sections*, which are obtained from a series of lines of levels in which distances, as well as heights, are taken, and which may be accompanied by a rough survey and plan, if the existing maps are not sufficient for the purpose.

When these operations have been performed, and the site of the line more or less accurately determined, the *Detailed Survey and Plan* may be proceeded with. Inasmuch, however, as the previous surveys have been merely of a tentative character, this new one, aided by additional trial sections, will be a more elaborate and exact production, and confined to the small amount of land finally selected for the site of the railway.

The next movements consist in the *Marking out of the Line;* the preparation of details and sections; trial excavating and boring, to enable the nature of the strata in relation to future cost of working to be ascertained; the preparation of the required working details, and general drawings of the line and its structures, in accordance with Board of Trade requirements; the taking out of the quantities of materials; the preparation of the specifications; and, indeed, everything else that can in any way aid the engineers and the contractors in forming an exact estimate of the difficulties to be encountered during the progress of the work, and also its cost, have to be carefully considered at every point before the constructive operations can be commenced.

When the extent and nature of all the embankments,

cuttings, tunnels, gradients, curves, bridges, etc., have been thus allowed for, elaborate advertisements are placed in the leading technical journals, inviting contractors to send estimates to the Consulting Engineer, or to the Secretary of the Company, for the construction of the line either as a whole, or in sections, according to the extent and nature of the undertakings. As the conditions, however, are of a rigid character, and the enterprise one that may involve considerable risk from various causes, a great deal of care has to be exercised by those who offer to become responsible for the performance of the work. Before, therefore, a contractor can make out his estimates, he must carefully examine the drawings and specifications, and also check the quantities of materials, to see if any lurking mistake exists which may prove a loss to him in the end. He may even have to make partial inspections of the country, and also trial borings, if necessary, to ascertain the nature of the strata for his own satisfaction.

The necessity for doing this may be gathered from the fact that in some places a line may run for part of its course over territory of a mountain-climbing, tunnel-cutting, precipice-bordering nature, which enormously increases the cost of the work at certain points. Sometimes, too, disagreeable discoveries are made which it is impossible to foresee. For instance, the Kilsby tunnel cost about four times the contract price, because a quicksand was found in its interior which involved enormous additional labour. This, however, is only one out of numerous cases, where, owing to most unwelcome changes in the strata between the borings, great extra cost has been the result. Incidents such as these, and many others of similar nature, are often very difficult to guard against, as the history of many great works abundantly testifies.

They also help to throw light upon the perils that beset vast undertakings in which the risk of the executive firm may be great.

From the above it will be seen that a contractor's education must be not only extremely varied, but eminently practical, as he has to battle with the forces of nature, and successfully overcome them by means of machinery and appliances that will best facilitate excavations and constructions in earth work; the crossing of rivers and morasses; the tunnelling of mountains; the building up of vast works in timber, and so on, as will be described in subsequent chapters.

Having satisfied himself at every point regarding the physical features of the undertaking, the contractor must base his estimate upon the current prices of materials delivered at his works, or at various required sites. The cost of workmanship due to existing wages must be carefully considered, and allowances made for any contingencies that may arise through unexpected fluctuations in the prices of materials, or through engineering difficulties that are impossible either to foresee or prevent, and in addition to these he must protect himself from the evil effects of strikes amongst the workmen.

If the railway is to be executed in a foreign country, the qualities of the labourers of various nationalities, and perhaps the difficulty of obtaining enough of them in a time of need, have to be taken into account, otherwise the contractor's association with that far off land may eventually produce most unhappy reflections. The salaries of his own staff, and his own reasonable profit upon the undertaking, have all to be considered, as well as many other points of minor importance, and when all is done that can be done, he may in the end lose all his trouble

and the contract as well, because his estimate was *not* the lowest. In this way, we are told, Mr. Brassey unsuccessfully tendered during his life for work representing a total value of £150,000,000. From this it will be seen that the career even of a great contractor is not always a happy one, hedged about as it often is with occult dangers of a serious and perplexing nature.

In proof of this, we have only to read the *Life and Labours of Mr. Brassey*, by Arthur Helps, which describes the career of a princely contractor whose very numerous works at home and abroad were sometimes on such a colossal scale, and of so complicated a nature, as to produce serious technical and financial difficulties. The fall of a viaduct; an earth work or tunnel turning out much more expensive than was expected; scarcity of labour; malarial ravages amongst the hands; and political changes of an adverse nature, being only a few of the evils he had to deal with in detail.

As an example of the latter, it may be said that when Mr. Brassey was engaged upon some of the Indian works, the estimates for which were based upon prices that ruled before the commencement of the Mutiny, the extinction of that revolt created so much activity in all the departments of labour after a period of enforced stagnation, that wages went up at least 30 per cent., and even then, the desired number of men could not be had. The most serious combination of adverse circumstances, however, occurred in 1866, when his troubles from a variety of sources, sufficient to have overwhelmed any ordinary individual, came upon him with a rush.

At this period he had liabilities amounting to £600,000 in connection with the Victoria Docks, London; £800,000 on Danish railways; £1,200,000 on the Lemberg and

Czernowitz line in bonds that had become worthless; while at the same time he had to go on with the works as if nothing had happened, and pay about £50,000 a month in wages alone on the last named contract. Amongst other projects of a losing character at that period may be mentioned the Queensland railway; lines in connection with the Great Western, Great Eastern, and other home railways, etc. Indeed, the liabilities flooding in upon Mr. Brassey in that most eventful year were so enormous, that it was surprising he eventually emerged in safety from them. The devoted friends, however, he had already made, stood by and helped him most kindly, until he passed through the dark cloud of adversity into the sunshine of prosperity.

Besides his merely technical qualifications, Mr. Brassey possessed the gift of organisation to a marvellous degree, and also the power of anticipating the results of various movements with great accuracy and clear sightedness. He selected his agents with consummate care and judgment, with the object of placing full trust in them, and while he himself was a master of details, he left these to his subordinates in such a way as to give him perfect freedom in exercising his powers as commander-in-chief of numerous simultaneous undertakings at home and abroad. He was very generous towards those he employed, and in matters of dispute was equally so. His temperament was singularly calm and equable, success or failure, even great failure, seldom discomposing his serenity of mind, and while he eventually acquired an immense fortune, few could have cared less for the money itself.

Taken for all in all, therefore, Mr. Brassey was one of those truly good and great men who have left their footprints on the sands of time, footprints which perhaps

another, some forlorn and shipwrecked brother—or sister—seeing may take heart again.

When our Baratanian scheme had been carefully matured under the wise supervision of Sir Julius Greville, and when the estimates from various firms had been examined and commented upon by competent judges, those of Messrs. Brown, Jones & Co., of London, were accepted, not because they were the *lowest*, but owing to the fact that it was well known that their slightly higher prices would be counterbalanced by superior all round excellence in construction. This, Sir Julius had emphatically pointed out to the directors, who quite agreed with him.

Upon being informed of the result of their labours, the above firm immediately engaged a sufficient number of skilled hands, and obtained the necessary machinery and appliances for enabling them to commence operations. All these were shipped without delay, and eventually arrived at Deephaven in safety. Of course, this projected undertaking had been for some time past the main topic of discussion on the island, owing to the urgent necessity that had arisen for facilitating the trade that promised to expand enormously when proper communications and outlets could be provided for it. Now that the scheme was fully matured, and the executive staff had actually arrived at the scene of operations, the greatest enthusiasm prevailed on all sides, from Sir Sancho Panza the Governor, down to the humblest individual.

Sir Sancho was of Spanish origin, but having spent most of his days in England, was practically one who looked upon everything with British eyes and feelings. He and his good lady were, moreover, extremely popular with the inhabitants, on account of the wisdom and good-

ness they had so abundantly displayed whilst acting as Commanders-in-Chief of the new territory.

As everything must have a beginning, and as the commencement of a railway consists in what is termed the "*Cutting of the First Sod*," it is only natural that this important event should be hedged about with the most pleasant and auspicious circumstances. Hence, when it became known that arrangements had been made for the due performance of the ceremony on the following Tuesday, everyone seemed to consider that he or she ought to bear a hand in giving effect to the proceedings, which would certainly be unique so far as the Island of Baratania was concerned.

The grand day was one of sunshine and splendour, and everyone was on the move from an early hour. An air of "gr-r-eat excitement" seemed to pervade the whole population, and all the available flags were hoisted in conspicuous positions afloat and ashore, thus producing a very charming effect. The approaching event gave everyone a week-day opportunity of appearing in Sunday best costumes, and of smiling their approbation on all sides. With this in view, we may conclude that the railway about to be initiated commends itself to everyone. So much, indeed, is this the case, that the directors, the engineers, the contractors, and all connected with the undertaking, are greatly encouraged at the outset.

By twelve o'clock everything is ready, including the external and internal embellishments of a large marquee which has been provided for the visitors and others. A procession, headed by a band of music, marches to the spot where the First Sod is to be cut, around which the assembled company forms itself into a circle, the central portion being occupied by Sir Sancho and Lady Panza, and

the most prominent of the inhabitants and officials. The Chairman of the Directors now delivers a most interesting address, in which he clearly shows to his admiring audience the immense advantages to be derived from the railway when completed, and points out the probability of a very large population being drawn to its adjacent territory, in addition to the rapidly growing passenger and goods traffic now waiting for it. Finally, he alludes in most felicitous language to the honour conferred upon them by the presence of the Governor and his Lady, "to whom they already owe a debt of gratitude."

Upon finishing his oration he presents Lady Panza with a handsome spade of silver-mounted polished mahogany, and after receiving the necessary instructions, she commences the ceremony by pressing the spade into the earth and throwing a small detachment of it into an adjacent barrow of polished oak, exquisitely mounted in silver. The Governor now throws off his coat, and amidst the enthusiastic cheers of the multitude, fills the barrow, and then wheels it away, after which he leads the company into the marquee, where an elegant luncheon has been prepared. After a few speeches have been made, and replied to, Sir Sancho and Lady Panza depart amidst tremendous cheering and the firing of naval guns worked by blue jackets, taking with them at the same time the barrow and spade with which they had so successfully inaugurated the first grand undertaking in their island home, and which was destined to produce magnificent results in the future.

The phrase, "a line of railway," is one that has a very elastic significance, as it embraces so many more or less diversified physical peculiarities in the country through which it passes. The least expensive arrangement is one

that in straight line fashion traverses a perfectly flat territory, since in cases of this kind abroad, the sleepers are simply laid on the ground with a trench on each side to carry off the surface water. An interesting example of this on, we believe, the greatest scale, being the new Argentine Pacific Railway, which runs for a distance of 211 miles without a single curve.

At other times, a line may consist of only moderate gradients and curves, or, if in a hilly country, of slopes and windings of a more pronounced and frequent nature. In a mountainous region, however, not only are the two latter in great demand, but embankments, cuttings, and tunnels, sometimes of great length and most difficult construction, are additionally employed, as well as bridges and viaducts of every conceivable form and dimension. In short, a railway between two distant termini, may include one or more of each of the above, or all of them in combination, according to the physical peculiarities of the country through which it is to be carried.

As the *Canadian Pacific Railway* is one of the latest and most gigantic undertakings of this description, we may here refer to a few of its leading features. Previous to the construction of the line, the country through which it had to pass was unexplored, and included a vast region where deep lakes and great rivers in every direction opposed the progress of the engineer. For 1,000 miles beyond the Red River stretched an immense plain, then came the mountains, range after range in rapid succession, and through all this territory, for a distance of nearly 2,000 miles, the surveys had to be made at a great expenditure of time and money. People became impatient, and found fault with the scheme. There were serious differences of opinion on the subject, so much so, indeed, that it was not until

1875 that the work of construction was begun by the Canadian Government.

The explorations and surveys for the railway had exposed the character of the country it was to traverse. In the wilderness bordering on Lake Superior, forests of pine and other useful timber, mineral deposits of incalculable value, and millions of acres of agricultural land were found. The vast prairie land between Winnipeg and the Rocky Mountains proved to be wonderfully rich in its farming resources. Towards the mountains, great coal fields were discovered, and British Columbia beyond them all, was known to contain nearly every element of traffic and wealth. Thousands of people had settled on the prairies of the north west, and their success had attracted tens of thousands more. The political reasons for constructing the line were lost sight of, and there was no difficulty in finding a party of capitalists ready to relieve the government of the undertaking and carry it on as a commercial enterprise.

In this way the Canadian Pacific Railway Company was formed in 1881, and immediately afterwards entered into a contract with the government to complete the line within ten years. As the latter had granted numerous privileges and immunities, and substantial executive help, the work of construction was vigorously commenced at Winnipeg, and pushed westward at great speed.

Some idea will be formed of the rapidity with which a prairie line may be laid, when it is known that for months in succession the average rate of advance by the Company's staff was fully three miles a day, sometimes, too, as much as five, or even six miles, was attained in the same period. By the aid of armies of men having all the best appliances, and thousands of tons of dynamite for blasting

purposes, the end of the third year found the railway at the summit of the Rocky Mountains, and the fourth in the Selkirks, nearly 1,050 miles west of Winnipeg. During this period, the government section of the line from the Pacific coast was carried on with the utmost despatch, until both forces met at Craigellachie, in the Columbian range of mountains, and there, on November 7th, 1885, the last rail was laid.

The energies of the Company had not been confined to the mere fulfilment of its contract with the Government, much more having been done to enable the railway to become a successful enterprise. Independent connections with the Atlantic coast were secured by the purchase of lines leading eastward to Montreal and Quebec; branch lines to the chief centres of trade in eastern Canada were made to collect and distribute the traffic of the main line, and other branch lines were laid in the north-west for the development of the great prairies.

The end of 1885 found the Company in possession of no less than 4,315 miles of railway, including the longest continuous line in the world, extending from Quebec and Montreal to the Pacific Ocean — a distance of 3,050 miles—and by the middle of 1886 all this vast system was in full working order. Villages, towns, and cities, followed close upon the heels of the constructors. The forests were cleared away; the soil of the prairie was turned over; mines were opened; and even before the last rail was in its place, the completed sections were carying a large and profitable traffic. The influence of the Canadian Pacific Railway upon the commerce of the world was felt from its very outset, and to such an extent as to affect, in a marked degree, the trade of China and Japan, by means of magnificent 6,000 ton mail steamships,

which were specially built to run from Vancouver westward to the far east.

The three years, from 1886 to 1889, were marked by an enormous development of traffic, and by the addition of 800 miles of railway to the existing system. These lines spread in various directions, with the object of benefiting the numerous mining, agricultural, manufacturing, and other districts. And as the Company's lines have so long been completely organised, the natural question "*Do they pay?*" is answered by the fact that the earnings over the whole system have been of a very satisfactory nature, notwithstanding long sustained periods of commercial depression. Canada's steel built roads have given such an impulse to all her industries that the modest colony of the past is now an energetic nation, with great plans, and hopes, and benefits to confer upon her ever increasing population.

In proof of this, we have only to refer to such places as Winnipeg, a mere frontier trading post before C. P. R. times, but soon afterwards transformed as if by magic into the great commercial centre of the north-west territory. Take Portage-la-Prairie, another city of a day's growth, and the centre of a well developed and prosperous farming region. In addition to these take Brandon, of marvellously rapid growth, and towns of lesser degree too numerous to mention, as specimens of what small communities may become when fostered by a great railway and its tributaries.

From the foregoing remarks, it will be seen that the Canadian Pacific Railway is not only the most gigantic of recent undertakings, but one which combines in itself many of the most varied and difficult features of engineering practice. It also shows, on a prodigious scale, how an uninhabited wilderness may be so altered as to

become a fruitful garden, and the nucleus of vast and thriving populations which greatly increase the revenue of the line, whilst they themselves are greatly benefited by its presence.

The *Engineering* features of the railway above referred to are very peculiar, as may be partially gathered from the fact that, after running for many hundreds of miles over plains, the approach to the Rocky Mountains marvellously changes the character of the line. Upon entering the latter from a low level on the eastern side, it gradually rises until *Stephen's Pass* is reached at an elevation of 5,296 feet above the sea level. It then descends rapidly on the western side of the mountains, where at one particular spot a maximum gradient of 1 in 22, four miles in length, formerly existed. For this, however, another route has been substituted, with a gradient of 1 in 45 for the sake of more easy working.

From the summit to the western base of the Rockies the line descends 2,742 feet in 43 miles, by means of straight and also zigzag inclines of varying steepness, and curves whose minimum radius is 190 yards. It next traverses a somewhat level country between the Rockies and the Selkirk range, then rises 1,920 feet in 18 miles, and after crossing the latter at a still higher altitude, it descends 2,830 feet in 47 miles. Here, however, the mountain climbing, and ravine spanning, and giant precipice verging are at last fairly cleared, and the worst is over on the road to Vancouver.

It may be mentioned that as the traffic on the above lines had to be created at the outset, they were originally built in a very inexpensive style throughout. Owing, however, to the enormous development of their transport service, it recently became necessary to have

stronger built roads, and in very many cases steel bridges, instead of the original timber trestle structures, which, up to a certain point, did well enough. This reconstruction on a colossal scale, and on the most improved system, has already added greatly to the success of the work, and shows clearly how the permanent way of a vast system can be advantageously altered to suit surrounding circumstances.

The descriptions we have given of the commercial and physical features of the Canadian Pacific Railway, which now possesses at least 7,000 miles of line, will help to throw much light upon it. With this in view, it will not be difficult to practically sketch out, on a smaller scale, some of the peculiarities of our Deephaven and Bathurst line, and to explain in detail in other chapters the machinery and appliances by whose aid its construction will be most efficiently and economically carried out.

CHAPTER IV.

THE DEEPHAVEN AND BATHURST RAILWAY DURING CONSTRUCTION.

Earthworks described — Cuttings and their Difficulties — Examples from Practice — Mr. Brassey and his Colleagues — Causes of Earthwork Slips—Railway Construction—Ballast and its Uses—Stone-breaking Machinery—Sleepers and their Treatment—Creosoting Process—Machining Operations—Manufacture of Chairs—Rails and their History—Introduction of Steel Rails—Improvements in Manufacture — Testing Machinery — Official Tests by various Companies—Splicing of Rails—Laying of Rails—Heat Expansion Allowances—Midland Railway Experiments upon Rail Fastenings—Present System—Considerations affecting Permanent Way Details—Automatic Ballasting Machinery.

IMMEDIATELY after the ceremony of cutting the first sod, mentioned in the last chapter, had been successfully performed, the agents of Messrs. Brown & Jones began to make preparations for starting the works, and with all the more energy as the contract stipulated that while, on the one hand, a premium should be paid to the builders for every week of completion before the specified time, a penalty would be similarly enforced for delay *beyond* that period.

For the sake of making the line more interesting, let us suppose that it includes a few level portions, extremely varying gradients and curves, cuttings, embankments, tunnels, and viaducts; primeval forests that have to be penetrated; and a series of bridges of diversified kinds. All these have been more or less formidable obstacles on

innumerable railways, and as they will still be on many others, we hope to show, as we get along, how the work is now accomplished by the aid of the latest appliances and improved systems.

The term "*Earthwork*" is generally applied to excavations or cuttings, and fillings or embankments. Cuttings are of an extremely varied nature, and may be, on the one hand, of the most trivial dimensions in mere earth; or, on the other hand, of the most gigantic and costly description in the hardest granite, etc. In addition to the ordinary difficulties that are foreseen in any great undertaking, may be mentioned the exposure of the sides of deep cuttings to landslips, owing to the unexpected presence of water, which has often caused great trouble and delay, many examples of which might be given. For instance, at a certain place on one English railway it was calculated that about 50,000 cubic yards of earth would have to be removed, but upon the severance of a seam of shale that supported the superincumbent earth, the latter slipped to the bottom of the cutting, thus involving the removal of no less than ten times the above quantity of material.

Perhaps one of the most difficult undertakings of this nature occurred near Haslingden, where 500,000 cubic yards of peat, gravel, and sand had to be taken from a cutting where, owing to the presence of a large quantity of water, the material sometimes fell in at a faster rate than it could be taken out. Eventually, however, the difficulty was overcome by sinking large masses of stone at certain points, thus displacing so much of the peat as to provide a solid bed upon which the line could be carried in safety. Those who remember the difficulties encountered by the contractors of the Manchester Ship Canal, whilst excavating its channel of thirty-five miles in length, and nearly

fifty feet in depth, will realise, to some extent at least, the secret sources of danger to be met with when least expected.

These, and many other similar examples, will give some idea of the treacherous nature of works in earth which the contractor has to provide for as far as possible whilst preparing his estimate, in order to protect himself from disastrous losses.

One of the most remarkable cuttings in *rock* is that of the "Olive Mount," on the Liverpool and Manchester line, where, for nearly two miles, the railway traverses an artificial ravine with perpendicular walls in some places more than 100 feet in height, and of a width between them only sufficient to clear the drains on both sides of the line. Naturally, we should have expected a tunnel at this point, but various considerations prevented it, one of them being that the material was required for building purposes. Here, too, it may be observed that works of this nature incidentally provide large quantities of stone and earth for bridges, viaducts, embankments, &c., along the line, thus forming a good example of the manner in which railway engineers utilise their surplus products, and provide constructive materials without the trouble and expense of getting them from distant sources.

The deeper a cutting is made the more expensive it becomes, until a point is reached at which it is cheaper to make a tunnel instead, or at least, the two systems may so balance each other in cost that it is sometimes only a matter of choice which to adopt. During the construction of the Midland railway Mr. Barlow, the engineer-in-chief, occasionally substituted tunnels for cuttings, the reason in at least one case being the difficulty of finding space for depositing the much greater quantity of material supplied

by the latter. In works of this class a large amount of additional cost is often incurred through great variations in the strata, a good example of which was found in an excavation on the Settle and Newcastle line, where shale, mountain limestone, magnesian limestone, grit, slate, iron, coal, and lead ore, in thin bands, were all found within a distance of one hundred yards.

When discoveries of this nature increase the cost of operating at any particular spot it may embarrass the contractor, who has fixed his prices upon the expectation of having less troublesome work to perform. In cases of this kind Mr. Brassey had a very nice way of overcoming the difficulty with those who helped him. If, for instance, a cutting supposed to be in clay turned out in a short time to be rock, the sub-contractor had no difficulty in obtaining an extra allowance after his principal had examined the work for himself. Sometimes, moreover, this was done quite spontaneously, as Mr. Brassey during his rounds noted everything, and would not allow his colleagues to lose when once he knew the true state of affairs. From the manner in which all grievances were thus redressed, the visits of the commander-in-chief were invariably a source of much gratification to everyone.

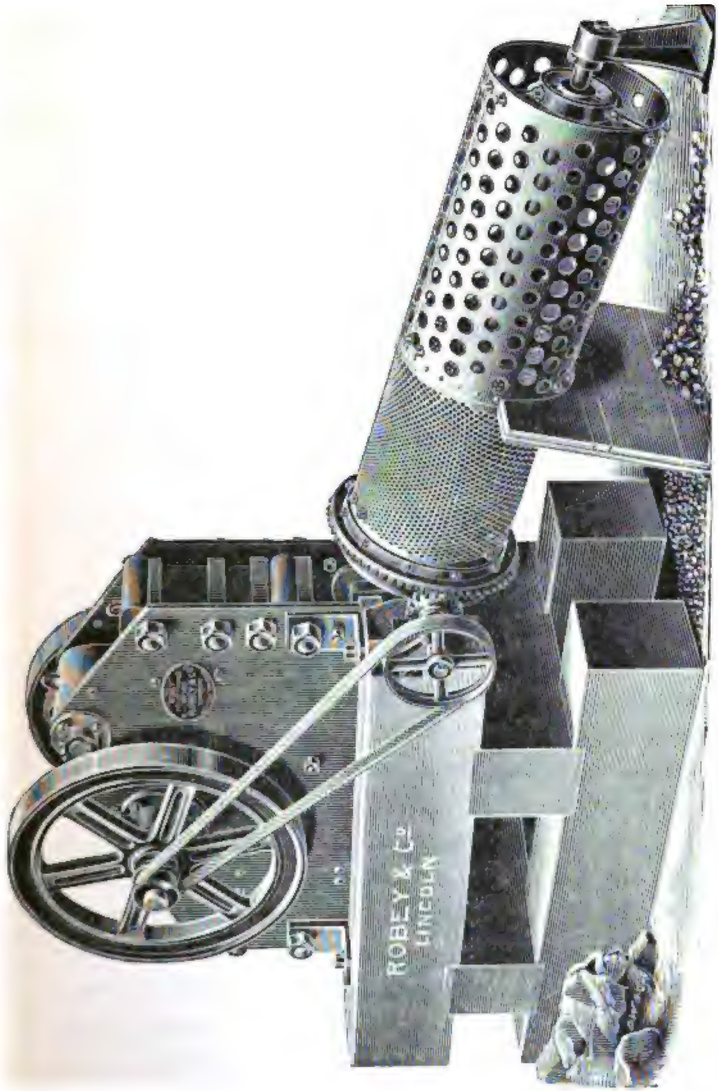
After everything has been done that can be done to secure the best practical results, and, indeed, after the sides of cuttings have stood for months, or even years, they have at times either loosened or slipped owing to the accumulation of water behind the earthwork, or perhaps from chemical action, which has occasionally had a most important part to play in this respect. Slips thus created might be supposed by an ordinary observer to be due to want of care or skill on the part of the engineer. With some materials, however, the action of time and weather

occasionally produce chemical changes that are almost irresistible, thus forming another of the dangers which involve serious delay and expense that cannot well be avoided.

The most rudimentary of all railway constructive performances is that of laying a line upon a level plain, but simple as this operation may appear to be, certain precautionary measures are necessary to avoid future failure. Of course, some may imagine that placing the sleepers on *bare* ground is quite sufficient, but in England, at least, this is not the case, as they might rot, and thus create subsidences that would endanger the traffic of the line. To avoid these evils, the sleepers are bedded upon ballast carefully laid for the purpose on the formation level, or top of the earthwork. This ballast usually consists of broken stone of suitable dimensions, and from 1′ 3″ to about 2′ 0″ in depth, thus producing a foundation through which the water percolates, and then passes into a drain upon each side of the line.

Now how are the immense quantities of this material used on railways to be economically obtained? Some of us may remember the very slow and laborious manual operation of roadside stone-breaking in early days for the purpose of keeping the highways in good order. Mr. Blake, spying this out, conceived the happy idea of mechanically performing the same operation, the result being his invention of the *Stone Breaking Machine*, which Mr. H. R. Marsden has so greatly improved as to make it one of the most highly-appreciated machines of the age. So powerful is it that it will crush the hardest stone, one alone being able to produce from 30 cwt. to 22 tons of road ballast per hour, according to size.

The simplest and most portable form of this machine



STONE BREAKING MACHINE.

for bad road, or for mountain transit, is one by Messrs. Robey & Co., shown on the preceding page; the framing of which is of rolled steel plates, for lightness. It is still further made in pieces, capable of being easily carried on the back of a horse or a mule, the timber foundation being equally portable. As the stone becomes crushed by the internal vibrating jaws it falls into a revolving pipe, which is perforated with holes through which the broken material passes when reduced to the regulation sizes ready for use on the line.

The *Sleepers* are sawn in prodigious quantities to the standard dimensions of 9′ 0″ in length, 10″ in breadth, and 5″ in depth. They also have the spike-holes bored through them in the exact transverse and longitudinal positions, so that not only will the chairs or flat-bottomed rails fit unerringly to their places with the least amount of trouble, but every spike will require the same force to drive it home without splitting the wood by the process. These *spikes* are usually about 6″ long, and of ¾″ diameter rod iron, with cupheads for chair fastenings, but when employed for securing flange rails directly to the sleepers the heads are specially formed, and are made capable of being so powerfully clipped as to enable the spikes to be withdrawn at any time.

Sleepers for lines such as the above are generally spaced about 3′ 0″ centre to centre throughout, and 2′ 2″ only at the joints, but in every case the bearing area is so proportioned as to distribute the weight of the rolling load on the ballast beneath them in the most judicious manner. They also form admirable ties for the rails, whose gauge is maintained more or less perfectly according to the manner in which the latter are secured to them. Various kinds of timber are employed for sleepers, one of the

most popular being Baltic pine, but as all are liable to rapid decay if not sufficiently protected, we may here describe one of the best processes used for this purpose, that of Creosoting.

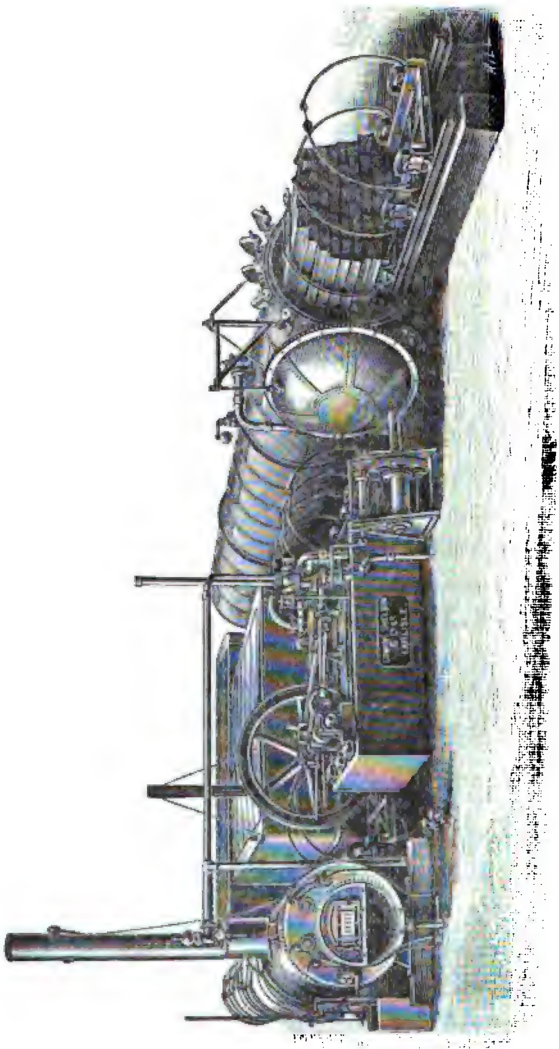
Creosote is obtained by the distillation of coal-tar, and possesses antiseptic properties that prevent the timber impregnated by it from being attacked by worms or insects. When the oil is forcibly injected into thoroughly seasoned wood, it closes up its pores, and excludes moisture so effectually as to protect the timber from dry rot, etc., the manipulative operations that ensure this being as follows:—

In the first place a wrought-iron cylinder, capable of being closed at the ends, and varying in length from 20 to 65 feet, and about 6 feet diameter, is used. Underneath this a tank is placed containing the oil, and along the bottom of the inside of the cylinder is a line of rails, which also extend some distance outside. On this railway small iron frames are made to run so as to facilitate the charging of the cylinder with sleepers in a manner that will allow the oil to percolate freely through them in every direction.

When the timbers are laid in their places the ends of the cylinder are bolted on, so that the air contained in it may be pumped out, the creosote from the tank at the same time entering the barrel through a pipe until the latter is fully charged. Oil is then forced into the cylinder until a pressure of 130 to 170 lbs. per square inch is obtained, under which the sleepers are kept for various periods, according to circumstances, at a temperature of 90° to 100° Fah., in order to prevent the oil from crystallising in the pores of the wood during the operation.

Sleepers thus treated have lasted in some cases upwards of 16 years, but taking the average of various

railways, 8 to 9 years is about the limit of endurance.



SLEEPER CREOSOTING PLANT.

This, however, is probably due more to bad usage than to the effect of decay.

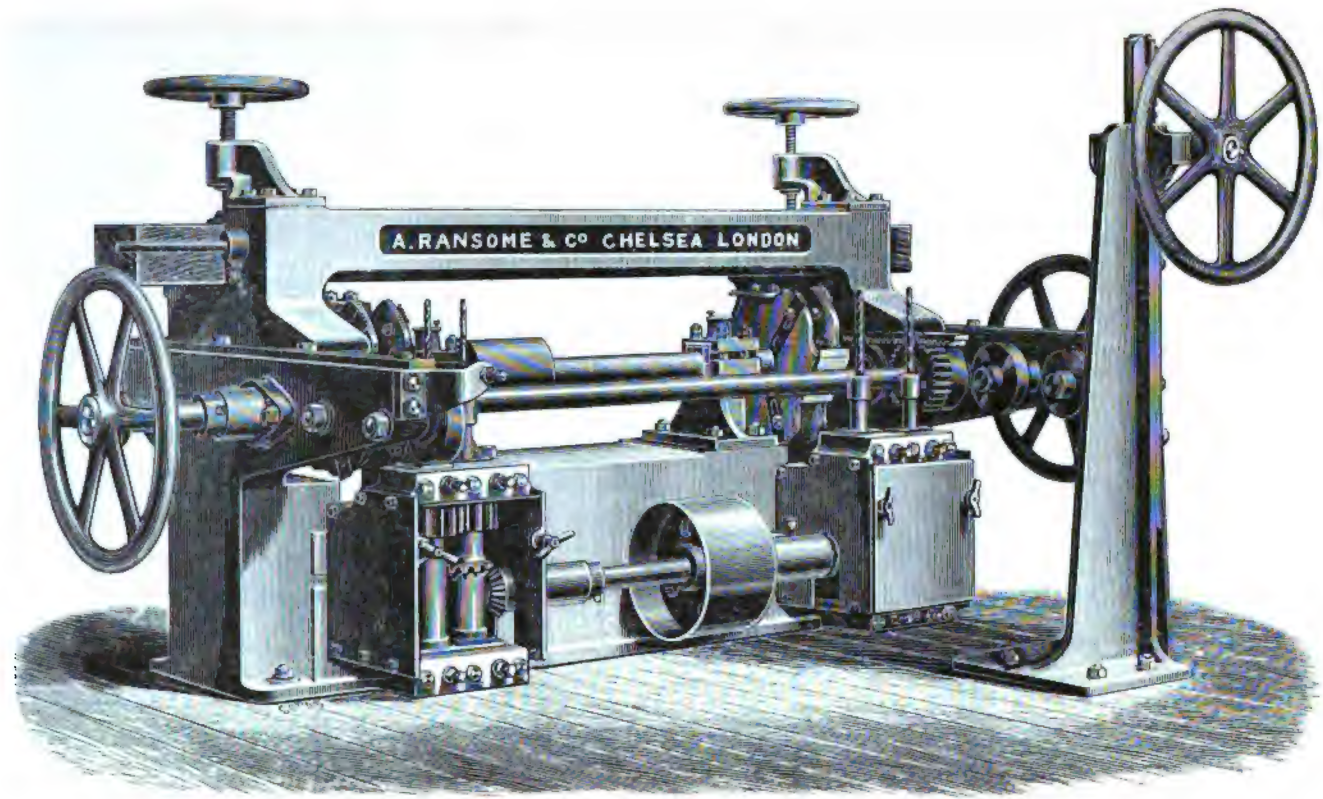
In the accompanying view of a *Creosoting Plant* by Messrs. Cowans, Sheldon & Co., the process is clearly illustrated. The main cylinder is seen in the act of receiving the sleepers, the circular door being swung into position by means of a small crane, and then bolted up when the latter are in their places.

On the left-hand side is a boiler which supplies the engine with steam, and adjacent to it is the tank containing oil that has to be pumped at high pressure into the sleeper chamber, the winch in the foreground being used for lifting purposes by means of overhead tackle. It may be added, that the parts shown in the illustration were merely arranged conveniently in the works of the above firm, so that they might be photographed before leaving.

With the object of fitting the sleepers for the reception of the rails and chairs, Messrs. Ransome provide the *Combined Sleeper Adzing and Boring Machine*, illustrated on the next page, which represents a very effective method of preparing both the seatings for flat-bottomed rails and boring the spike holes at one time.

The sleeper shown in position is cramped upon a strong sliding carriage running on rollers, and is caused to pass over rapidly revolving cutter blocks by means of hand wheels. These cutters—one of which is shown in the view—are of a width suited to that of the rail or chair flange, and notch out both seatings simultaneously. An adjustable stop against which one end of the sleeper is pressed before being cramped to the table automatically ensures the greatest accuracy in the position of the seatings without the trouble of marking them off.

The spike and treenail holes are bored by means of four vertical spindles arranged in two carriages, which can be adjusted when required to bore holes in the exact position



COMBINED SLEEPER ADZING AND BORING MACHINE.

to suit different curves. A vertical rack and hand-wheel bring all the drills into play at the same time, and as they work *upwards* instead of downwards, their action is more easy on account of the chips falling out.

When *Chairs* are used they are made with great exactness from full-sized drawings, and as they are moulded by special machinery their cost is reduced, and their production facilitated to the utmost. In England this is most important, owing to the enormous numbers of them that are required.

The conditions that guide their designers are as follows:—The section of rail and method of keying it to the chair; the system of permanent way employed; the size of the sleeper and the kind of wood; the distance of the sleepers apart; the maximum load on the rails due to any pair of engine wheels; and the speed of the trains.

The *Rails*, to which we now come, have quite a history of their own; those, however, that were once so popular have been so completely superseded by two distinct systems which have grown out of them, that to these alone we shall refer. The original fish-belly rails and their immediate successors appear to have done more or less good service in the past, but their imperfections and failures, combined with a swiftly growing traffic of a heavier and more rapid nature, caused many improvements to be made.

The immense importance of having our steel roads as perfect as possible becomes clearly apparent from the fact that it is by their excellence at every point, and the smoothness in running they naturally create, that damage to the ballast, injury to the sleepers, fracture of the chairs, crushing, and, perhaps, breaking of the rails, increase of resistance to the passage of trains, and severe wear and

tear of the rolling stock and its machinery, including great discomfort to passengers, are avoided. Indeed, it may be said that, without the excellence referred to, the whole of the statical and dynamical systems of a railway would so rapidly become disintegrated unless constantly renewed, and so many terrible accidents would result, that a line which began auspiciously would end disastrously.

As the fish-belly rail of 1820 made a good show in theory, it became popular for a time, but as it was troublesome to make it was superseded by the flat-bottomed rail of Mr. Vignoles, which has been so much improved in form and proportions as to be the one most in use all over the world, both for light railways, as shown in our illustrations, and also for those of the heaviest class. Inasmuch, however, as exposure to severe wear of the top part of the rail made it soon become useless, Mr. Locke invented the double-headed rail, which in England, until recently, was most generally employed, owing to its great strength as a beam, but chiefly to its capability of being turned when the top side became too much worn. Here, however, theory was again baffled by experience, as the part that rested upon the chair became so indented by the hammering action of the traffic as to render it unsuitable for smooth running when turned.

This led to the introduction of the bull-headed rail, whose top bulb was made larger than the bottom one for the sake of good wear, and in this respect it has answered so admirably as to have displaced its predecessor.

Up to the year 1862, all the above rails were of iron, but so enormously had the traffic expanded by this time, and so rapidly had the weights and speeds of engines increased to enable this traffic to be satisfactorily worked, that the iron rails then in use were bent, laminated, and

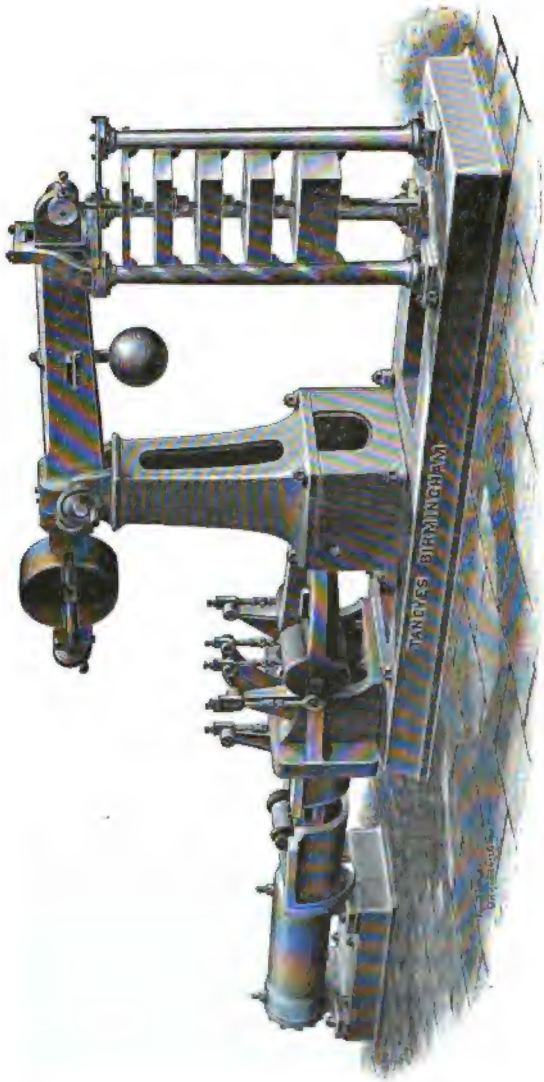
split by the pounding strains they were subjected to. They were also ground, severely worn, and torn by the skidding action of the wheels when checked by the powerful brakes, hence irregularities in running were introduced, and the life of the rails so much shortened as to indicate the need of the employment of some more durable material. Thus arose the demand for *steel* rails, some of which were so successfully laid down by the London and North Western Railway Company as to open out a way for others on a greatly extended scale.

These at first were rather costly, but the inventions of Bessemer, Siemens, and others, introducing improved methods of manufacture, so diminished the cost of production as to rapidly change the original iron roads into lines of steel, whose superiority is due to their greater strength and perfectly homogeneous texture, by means of which the faults incidental to iron are avoided.

The *Tensile Strength* of steel is greatly diversified, and may be said to range from the Board of Trade allowance of 26 to 30 tons per square inch for ship and boiler plates, and 58 tons special limit for wheel tyres, up to 120 tons for wire, depending more or less in each case upon the ingredients used in the metal, and the mechanical treatment it receives, both of which sensibly affect its quality.

As in Chapter VIII an illustration is given of a Buckton machine for tensional, compressional, deflectional, and torsional testing purposes, we show on the next page one of Messrs. Tangye's 50-ton *Hydraulic Tensile Testing Machines*, in which water power is employed to create the stresses. These are produced by means of a combination of knife edged levers and weights, the former having a total ratio of 100 to 1, whilst the cylinder shown on the extreme left of the view is suited to a working pressure of

4000 pounds per square inch. Between this cylinder and



HYDRAULIC TENSILE TESTING MACHINE.

the adjacent gear, samples up to 6 feet in length are

securely clipped, and then torn asunder, the result being accurately registered.

Rails are also subjected to falling weight and dead weight tests, which are regulated by their sectional area. In the case of a rail, say, 70 lbs. per yard, placed on bearings 3′ 6″ apart, two blows from a one ton mass of metal, falling from a height of 18 feet, should not produce a permanent deflection exceeding 3″. Nor, supported in the same manner, should it deflect more than $\frac{5}{8}$″ with a dead weight of 28 tons on the centre of the specimen.

As examples from the practice of various Companies, with materials manufactured and experimented upon by Messrs. Charles Cammell & Co., of Sheffield, we give the following, which have been kindly supplied by that firm:—

MIDLAND RAILWAY TEST FOR BESSEMER STEEL RAILS.

Weight per yard, 85 lbs.	Bullhead section.
Length tested, 30 feet.	Centres of bearings, 3′ 6″ apart.
Height of fall, 12 feet.	Falling weight, 1 ton.

TEST.—Rails to stand without breaking two blows, the deflection after the second blow not to exceed 3″.

EXAMPLES OF TESTS—BY FALLING WEIGHT.

No. of Test.		1st Blow.		2nd Blow.
1.	...	$1\frac{3}{16}$″ deflection.	...	$2\frac{1}{4}$″ deflection.
2.	...	$1\frac{1}{4}$″ ,,	...	$2\frac{3}{8}$″ ,,
3.	...	$1\frac{1}{8}$″ ,,	...	$2\frac{3}{16}$″ ,,

EXAMPLES OF TESTS—BY TENSION.

No. of Test.	Original Section of Test Piece.		Breaking Strain.		At Point of Fracture.		Reduction of Area per cent.	Elongation.	
	Size.	Area.	In lbs.	In tons per sq. inch.	Size.	Area.		In 2″	Per cent.
1	·565	·25	23,100	41·24	·46	·166	33·6	·40	20·0
2	·565	·25	22,200	39·64	·45	·159	36·4	·44	22·0
3	·565	·25	23,300	41·60	·47	·173	30·8	·39	19·5

Great Western Railway Test for Siemens-Martin Steel Crank Axles.

Pieces taken from the top of ingot end of the crank :—

Tensile Test.—To stand not less than 30 tons, nor more than 35 tons per square inch. Elongation to be not less than 25% in 2″.

Bending Test.—A bar planed 1¼″ square by 9″ long, corners rounded, subjected to a simple bending test, ends being brought together as directed by inspector.

Pieces taken from one of the webs :—

Tensile Test.—To stand not less than 30 tons, nor more than 35 tons per square inch. Elongation not less than 20% in 2″.

Bending Test.—Bar 1¼″ square by 9″ long, corners rounded; bearings 6″ apart; falling weight, 10 cwts.; height of fall, 6″. Bar reversed after first and every alternate blow. To stand 20 blows without sign of fracture, the fall to be then increased to 12″, and the test to be continued until fracture takes place.

Example of Tests—by Tension.

No. of Test.	Original Section of Test Piece.		Breaking Strain.		At Point of Fracture.		Reduction of Area per cent.	Elongation.		Remarks.
	Size.	Area.	In lbs.	In tons per sq. inch.	Size.	Area.		In 2″	Per cent.	
1 (End)	·798	·50	34,950	31·20	·49	·189	61·7	·65	32·5	Bending piece doubled.
1 (Web)	·798	·50	35,800	31·97	·50	·196	60·3	·72	36·0	Bending piece unbroken.
2 (End)	·798	·50	35,100	31·34	·52	·212	57·0	·69	34·5	Bending piece doubled.
2 (Web)	·798	·50	34,800	31·07	·50	·196	60·3	·67	33·5	Bending piece unbroken.

General Test for Ordinary Wagon Axles of Bessemer or Siemens-Martin Steel.

Centres of journals, 6′ 6″. Journals, 8″ long by 3¾″ diameter.
Diameter of wheel seat, 5¼″. Diameter in the middle, 4½″.

Falling Weight Test.—To stand without fracture five blows from a weight of 2,000 lbs., falling from a height of 20 feet upon the axle which is placed upon bearings 3′ 6″ apart, centre to centre, and turned after each blow. After the fifth blow the axle to be broken for the examination of the fracture.

TENSILE TEST.—To stand not less than 35 tons per square inch, with an elongation of 25% in an effective length of 3″.

One axle from each 50 to be tested.

EXAMPLE OF TESTS—BY FALLING WEIGHT.

No. of Test.	Deflection.					Remarks.
	After 1st Blow.	After 2nd Blow.	After 3rd Blow.	After 4th Blow.	After 5th Blow.	
1	$3\frac{5}{8}$″	Straight	$3\frac{1}{4}$″	Straight	$3\frac{1}{8}$″	Axle reversed after each blow.
2	$3\frac{1}{2}$″	Straight	$3\frac{1}{4}$″	Straight	$3\frac{1}{4}$″	
3	$3\frac{3}{8}$″	Straight	$3\frac{3}{8}$″	Straight	$3\frac{3}{8}$″	

EXAMPLE OF TESTS—BY TENSION.

No. of Tests.	Original Section of Test Piece.		Breaking Strain.		At Point of Fracture.		Reduction of Area per cent.	Elongation.	
	Size.	Area.	In lbs.	In tons per sq. inch.	Size.	Area.		In 3″	Per cent.
1	·798	·50	40,700	36·33	·55	·237	52·6	·875	29·1
2	·798	·50	42,000	37·50	·56	·246	50·8	·84	28·0
3	·798	·50	41,800	37·32	·56	·246	50·8	·86	28·6

GENERAL TEST FOR ORDINARY WAGON TYRES OF BESSEMER OR SIEMENS-MARTIN STEEL.

Diameter on tread, 3′ 1″. Width, 5″. Thickness on tread, 2″.

PRESSURE TEST.—To stand without fracture being compressed 4″ by hydraulic power. Compression to be continued until tyre is broken.

TENSILE TEST.—To stand not less than 35 tons per square inch, with an elongation of 25% in an effective length of 3″.

One tyre from each 50 to be tested.

EXAMPLES OF TESTS—BY COMPRESSION.

No. of Test.	Pressure in tons.	Deflection.	Pressure in tons.	Deflection.	Remarks.
1	57	4″	63	8″	Tyre afterwards broken.
2	55	4″	62	8″	Tyre afterwards broken.
3	54	4″	61	8″	Tyre afterwards broken.

EXAMPLES OF TESTS—BY TENSION.

No. of Test.	Original Section of Test Piece.		Breaking Strain.		At Point of Fracture.		Reduction of Area per cent.	Elongation.	
	Size.	Area.	In lbs.	In tons per sq. inch.	Size.	Area.		In 3″	Per cent.
1	·798	·50	41,900	37·41	·52	·212	57·6	·88	29·3
2	·798	·50	42,800	38·21	·54	·229	54·4	·86	28·6
3	·798	·50	42,500	37·94	·54	·229	54·4	·83	27·6

Some may perhaps fancy that the above tests are of a very exacting nature; it must be remembered, however, that when steel came into use for constructive purposes it had many failures. Rails snapped unexpectedly and imperilled the rolling stock; ship plates gave way when they ought to have held fast, and marine boiler shells cracked and split so mysteriously as to endanger the safety of the ship which carried them. No wonder, then, that the Companies who transported the public over land and sea carefully noted these dangerous defects. So also did the Steel Works people, and therefore it was only natural that the chemistry scientists and the metallurgists should have combined their talents and energies with the object of rectifying these evils.

But even this was not enough, as the users of the steel, as well as its manufacturers, had no means of satisfying themselves on this point without extraordinary precautions. Therefore, with the past behind them as a warning, and the unknown future in front of them, the most rigid system of testing and supervision was instituted which ensured the desired quality of metal, and protected everyone concerned from dangers that might otherwise have arisen. Dangers, too, that were intensified by the fact that not only rails, but the engines themselves, and the main metallic parts

of the rolling stock, were made in enormous quantities of the new material. It may be added that, so extremely severe has the traffic now become on English trunk lines, that the leading Companies find it advisable to employ still heavier rails than those in general use to which the above tests refer, the Midland and other railways being at present partially re-laid with rails up to as much as 100 pounds per yard.

The term "fishing," when applied to joints or splices, was originally used to indicate the skilled carpenters' work of joining the broken or damaged parts of masts and spars, so as to make them temporarily strong enough. On railways, however, this process is of a metallic nature, but here, the fish plates owe their virtue to the manner in which their edges are made to bite the top and bottom flanges of the rails so powerfully as to transform them into solid and continuous beams. These plate fastenings are now practically perfect so long as the nuts of the four bolts that secure them in position are prevented from slackening by the vibration of passing trains, and this, numerous inventors have done their best to accomplish.

If we should pleasantly meander along a railway with two or three choice friends who wish to fully appreciate its engineering beauties, we might expect to have the apparent faults of rail laying pointed out to us as quite a discovery.

"Very bad workmanship, I should think," observes one of the party whilst gazing at the open ends of the rails so constantly visible, and bad indeed we certainly would call it under other circumstances. With this in view, let us try to throw some light upon what may be to many an obscure point.

In the first place, heat, when applied to metals, makes them expand more or less, according to their nature. For

instance, iron and steel, during a range of temperature from 32° to 212° Fahr., or 180° in all, expands in length 1″ in 833″. Taking, however, the total range of temperature at 90°, the expansion will then be $\frac{1}{2}$″, and as a 30 feet rail is 360 inches in length, we shall then have this rule:—

as 833″ : 360″ : : $\frac{8}{16}$″ : $\frac{8}{16}$″ full.

The real allowance, however, is about $\frac{1}{4}$″, and this covers everything that is likely to occur in practice.

Not only in rails, but in all metallic structures, where, if not provided for, heat expansion may do great mischief, the above thermo-dynamic law is taken into account, otherwise bridges would become dislocated, and exploded steam pipes would spread death and destruction all round, because their rigidly fixed straight lengths had no room to expand without crushing either their own bodies or their end attachments. Other evils, too, of a more or less dreadful nature throughout the realms of engineering, would be sure to follow, but to these we need not refer.

To the earnest student of engineering nothing, perhaps, can be more perplexing than some of the questions that are constantly arising in connection with matters of apparently insignificant detail, one of which was the placing of the wooden key that secured the rail to the chair. At one time these fixings were always put outside the rails; subsequently, however, the Midland Railway Company tried both inside and outside systems, the result being that while keys on the outside plan became loose and too often fell out, those on the inside held better.

It was found, nevertheless, that as the rails pressed *rigidly* against the outer jaws of the chairs, not only did the running of trains become more noisy and hard than they had formerly been, but the chairs themselves so frequently broke that the whole subject created considerable discus-

sion amongst engineers, who, up to this period, thought one plan practically as good as the other. Eventually the outside keys were most approved of, as they cushioned the blows of the wheel flanges upon the rails, and this led to a series of experiments with the object of effectually preventing the keys from leaving their seats, which, as mentioned above, was the original cause of complaint.

The *Permanent Way Details* mentioned in this chapter may be considered as follows:—The *Rails* may be treated as continuous girders, whose span is the *least* distance between two adjacent chairs, and whose working load is the greatest that can be brought upon them by one pair of wheels. They must also have sufficient bearing on the chairs to avoid undue cutting or crushing from the hammering action of the rolling loads.

The *Chairs* must not have too little bearing on the wooden sleepers, otherwise they may be crushed into the latter from the same cause, and, similarly, the *Sleepers* should have sufficient bearing to prevent them from sinking into the ballast.

The *Ballast*, on the other hand, though of solid nature, must be porous enough to let the surface water through, otherwise those disagreeable, if not dangerous depressions, will occur, to which Dr. Lardner attributed so much of the oscillating motion of trains amongst the "forties." The *Earthwork*, too, must be protected at all points from the action of water that may in time produce landslips and other evils of an insidious and undermining character. *Railroads* thus designed and constructed, and carefully maintained in good working order, are capable of carrying the most severe traffic with an amount of safety that is absolutely unparalleled.

CHAPTER V.

IN THE DEPTHS OF THE DEEPHAVEN RAILWAY WORKS.

On Level Ground—The "City of the Future" already in View—Concessions to Residents along the Line—Steep Gradients and their Difficulties—How Gradients act upon a Railway—Their Influence on Locomotives — Considerations affecting Engine Design — Standard Specification — Table of Tank Engine Dimensions—Tractive Power of Locomotives from present Practice—Special Table of Gradient Resistances—Simple Rules—Notes upon Permanent Way Construction—A Cutting on the Deephaven Line—Manchester Ship Canal and its Machinery—Gigantic Works—Mechanical Excavators—Embankment Construction.

As previously observed, the most rudimentary of all permanent way constructions are those that pass over a level, or at least a gently undulating country, such, for instance, as the prairies of America and Canada, where, for many hundreds of miles, a line may be run straight ahead without any obstruction. In cases of this kind, for pioneer lines, the ground may be only trimmed to a fair surface, but *without* ballast, as the population may be small, and the early prospects of success somewhat hazy. On our Baratanian line, however, these are continually becoming brighter, so much so, indeed, that, in view of the expected traffic, nothing but the most substantial system of construction will be suitable. As a proof that our course is a safe one, we may mention that recent discoveries of agricultural and mineral avenues to fortune, the enormous influx of new residents, the astonishingly swift enlarge-

ment of the town of Deephaven owing to the extension of its maritime commerce, aided by the pioneer light railways, have so developed the resources of the interior as to open out a path for the standard gauge line now in course of construction.

With all these facts in view, is it to be wondered at that enterprising speculators have already made preliminary arrangements for the building of towns and villages along the route of the line. True and faithful large scale plans of small but suitable portions of the land adjoining the railway have therefore been made, and upon these have been drawn in detail the proposed positions of villas, streets, squares, etc., the two latter having well-known names given to them, such as "Princes Street," "Oxford Street," "Belgrave Square," "Grosvenor Square," and so on, with the object of continually reminding the future inhabitants of the old country.

Wherever the hope of coming trade or manufacture has been strong enough, these "magnificent town plots" have been located upon a scale of grandeur that includes broad avenues, beautiful gardens, public buildings, etc. The block plans of all the buildings have been painted with crimson lake, the roads and streets washed with yellow ochre, the trees and shrubs of the gardens sketched in position, and painted a darkish green, the grassy parts being lightly tinted with the same colour, and all the water spaces indicated by artistic touches of Prussian blue. As the drawings are also beautifully printed, dimensioned, and finished off so as to look as intelligible and attractive as possible, and the prospectuses, now being extensively circulated, are telling their story most effectually in various countries, the result will probably be a rush upon the spots referred to by the strugglers and others from lands where

trade and commerce have more or less deteriorated, and where the prospects of success in life have become narrowed to a point.

Such indeed, we believe, will be the case in course of time, for the present, however, the fortunes of the future are only sketched on paper. Let it also be observed that the coming benefits so judiciously pictured are not all on one side, since not only will the settlers of the present and the future have their prospects wonderfully advanced by the presence of the railway, but they themselves in many ways will help to increase the revenue of the new line, as the history of the Canadian Pacific and many others will abundantly testify. The main cause of this is the liberality with which the Deephaven and Bathurst Railway Company has made concessions to those who intend to reside along its borders, and as these concessions will be mutually beneficial the anticipated success of the scheme is pretty well assured.

With all these facts in view, is it not reasonable that the Company should have decided to make their line as substantial as possible, and thus avoid unnecessary expenditure for maintenance, wear and tear, and occasional accidents of a disastrous nature? We think so. Although five miles of track have already been prepared, no earthworks of any consequence have yet been entered upon, as a few gradients have done all that was required to enable them to get comfortably over the inequalities of the ground. Here, however, we must explain the nature of these invaluable aids to railway construction which in various degrees of intensity are used to avoid the expense of cuttings or embankments.

As passengers can see for themselves, the authorities announce to their drivers all these little changes as they

travel along a line, hence we find, at numerous places, small white-painted wooden finger posts, which indicate that the portion of the track just entered upon is "level," or a slope downwards or upwards—as shown by the position of the arms—of "1 in 100," "1 in 250," etc., according to circumstances. Now, while these inclines greatly assist the railway, they act more or less prejudicially upon the engines and carriages, hence it comes to pass that it is the *maximum*, or ruling gradient, that chiefly determines the power of the locomotives for drawing up the ascent a certain load at a specified speed, smaller engines or heavier trains being available if the line were level throughout or had even a lesser ruling incline.

Although this gradient is the steepest on a railway for ordinary running purposes, and regulates to a large extent the economical construction of the latter, it is sometimes exceeded in places where high elevations have to be crossed within a comparatively short range of travel. Of this we have many examples in England, and in a still more remarkable manner on the Canadian Pacific line, where many of the inclines are very severe and difficult to work. Fancy, for example, a fall of say 200 feet in a mile occurring from time to time in a series of zigzags and otherwise, and where, to save a train from rushing to destruction in spite of its brakes, an engine has to be placed behind to hold it in check. The auxiliary engine referred to is not only thus most usefully employed, but it is of great advantage in helping trains over difficult points, and for this reason is kept in readiness wherever required. A rise of 1 foot in 100 may not appear to be much, but if it is continued for, say, 10 miles, it becomes 528 feet. If the slope should be 1 in 50, 1,056 feet would be the elevation, and so on for other degrees of horizontal angle in the

road. When a mountain has to be crossed, however, a series of inclines are arranged to suit the windings of the line, and these, as in the "Rockies," may be of the most pronounced character.

At one time it was considered best to plan a railway upon the level throughout principle when possible, because, although the cost might be greater than otherwise, the economical working of the rolling stock would be more easily attained. On the other hand, it was allowed by many that a series of moderate undulations were equally advantageous, because the momentum acquired in descending one of them was utilised in ascending an adjacent incline, as in the well-known Switchbacks, where no haulage power whatever is employed.

As a practical illustration of the application of both systems on a large scale, it may be said that a railway near Preston, where 5 miles out of 22 have gradients of 1 in 100, is worked at less expense than some of the more uniform lines. The London and Birmingham portion of the London and North Western Railway, and also a large tract of the Great Western, are, however, good examples of the uniform system. The former was constructed with the view of obtaining the most perfect level, or at least one whose ordinary inclines did not exceed 1 in 330, with the object of reducing the expense of working, the primary cost of the line having been quite a secondary consideration; and for the same reason the Great Western was made nearly a dead level for about 119 miles.

On the other hand, the London and South Western line has long and steep gradients and enormous earthworks, but without any of the colossal bridges, viaducts, or costly tunnels so often to be found elsewhere. In all cases, however, everything of a constructive nature due to the

absence or frequency and intensity of gradients, depends more or less upon the nature of the country traversed by them. So also does the total length of the line, as it may have many and serious deviations from the straight course, with the object of avoiding costly works.

Reference has already been made to the heavy inclines upon the Canadian Pacific and other railways, but probably the steepest in the world, worked by a locomotive, is that from Alpnack-stad to the summit of Mount Pilatus, where for a distance of fully two miles the average gradient is 1 in 2·50. In this case, however, the locomotives are so fitted with spur wheels, gearing into a rack placed between the rails, that a disastrous accident is practically impossible from a purely mechanical point of view.

Since the foregoing remarks refer only to the influence of inclines upon the permanent way, we may now consider their effect upon the engines themselves. Before doing so, however, it may be well to describe the leading points which determine the nature of the design and construction of goods or mineral locomotives, as given by the Hunslet Engine Company of Leeds.

(1) Clear gauge between the rails.

(2) Weight of rails per yard, and distance apart of sleepers.

(3) Length of journey the engine is required to make without stopping.

(4) Distance between watering stations.

(5) Description of fuel to be used.

(6) Radius of sharpest curve.

(7) .Length and gradient of the steepest incline, and whether the engine has to start on it or not. Also, if there are any curves on the above, the radius of the sharpest should be given.

(8) Greatest load in tons, including wagons or carriages, the engine is required to draw at one time.

(9) Height from top of rail to centre of buffers, and also their transverse distance from centre to centre.

(10) If limited to height and width of engine, extreme dimensions to be given.

The *Standard Specification* of the above includes the following leading particulars:—

Boilers to be made with longitudinal seams, double riveted. *Fire Boxes* of best selected copper plates, with rivets and stays of the same material. *Tubes* of solid brass carefully expanded in the tube plates by roller expanders. After being tested by hydraulic pressure and by steam, the boilers are lagged with tongued and grooved pine battens, covered with sheet iron, and neatly finished. Ample provision is made for cleaning the interior of boiler by means of wash-out doors and plugs.

Frames, well stayed to prevent them from working loose through severe straining. *Wheels*, *Tyres*, and *Axles* of steel, as well as the above. *Axle Boxes* of steel or cast iron, with gun metal bearings. *Buffer Beams* of oak, lined with iron plates on both sides, or wrought iron beams, well stayed to frames, and fitted with buffer and draw gear suited to the wagons, &c. *Hand Screw Brake*, acting on the wheels by cast iron blocks bearing on the flanges as well as on the tread of the tyres.

Cylinders of hard cast iron, with covers for easy access to pistons and slide valves. *Piston Rods* of steel, and pistons fitted with cast iron rings. *Valve Motion* of best iron, thoroughly case hardened. *Coupling* and *Connecting Rods* of best iron, fitted with adjustable gun metal bearings. One *Pump* and one *Injector*, or two injectors as may be considered preferable.

Ample water and fuel capacity, driver's cab, awning, or weather screen. All engines fully supplied with water and steam gauges, whistle, safety valves, steam jet, sand boxes, rail guards, lubricators, and other necessaries.

All *Steam* and *Feed Pipes* of solid drawn copper. A lock-up tool box, and a complete set of tools for the safe and efficient working of the engine are provided, and these include fire irons, pinch bar, full set of spanners to fit all sizes of nuts; hand brush, oil cans, copper, lead and steel hammers, chisels, &c., and also a traversing screw jack.

If required, the engines can be fitted with spark arresters, steam or automatic brakes, cow catchers, water lifters, liquid fuel apparatus, sanding gear, etc.

All engines are tested, and run under steam on the rails before delivery, which ensures the safety and proper working order of everything. As every locomotive is built upon the interchangeable system, their various parts can be exactly duplicated and held in readiness in the works for prompt transmission to any part of the world. To prevent even the possibility of delay, however, from this cause, the usual practice is to supply the spare parts likely to be required through wear and tear.

As we have shown elsewhere two views of narrow gauge, outside cylinder saddle tank engines, a few principal dimensions have been given of those for the 4′ 8½″ gauge, which have proved very serviceable for goods traffic, shunting and other purposes, including contractors' work of all kinds.

It may here be broadly stated that every engine on a railway has a certain amount of load-drawing or tractive power, which varies greatly according to its nature and size, the diameter of the driving wheels, the frictional hold of the latter upon the rails, train resistances, etc.

LEADING DIMENSIONS OF TANK LOCOMOTIVES BY THE HUNSLET ENGINE COMPANY.

Diameter of Cylinders	10"	11"	12"	13"	14"	15"	16"
Length of Stroke..	1' 3"	1' 3"	1' 6"	1' 6"	1' 6"	1' 8"	1' 10"
Diameter of Wheels	2' 6"	2' 6"	3' 1"	3' 1"	3' 1"	3' 4"	3' 9"
Length of Wheel-base	9' 6"	9' 6"	10' 3"	10' 6"	10' 6"	10' 9"	12' 0"
Capacity of Tank	300 gals.	300 gals.	500 gals.	550 gals.	580 gals.	600 gals.	800 gals.
Fuel Space	28 cub. ft.	29 cub. ft.	47 cub. ft.	47 cub. ft.	48 cub. ft.	50 cub. ft.	52 cub. ft.
Total Heating Surface	287 sq. ft.	300 sq. ft.	401 sq. ft.	489 sq. ft.	563 sq. ft.	695 sq. ft.	789 sq. ft.
Grate Area	6·5 sq. ft.	6·75 sq. ft.	7·375 sq. ft.	7·75 sq. ft.	8·25 sq. ft.	10 sq. ft.	14·75 sq. ft.
Weight of Engine loaded	14 t. 16 cwt.	17 t. 16 cwt.	18 t. 16 cwt.	22 t. 5 cwt.	24 tons	27 tons	35 tons
Radius of sharpest Curve.. ..	180 feet	180 feet	220 feet	230 feet	230 feet	260 feet	310 feet
Weight per yard of lightest Rail	30 lbs.	36 lbs.	40 lbs.	45 lbs.	50 lbs.	55 lbs.	75 lbs.
Tractive Force in pounds	4,500	5,446	6,304	7,400	8,580	10,126	11,220
Mean steam pressure per sq. in.	90 lbs.	90 lbs.	90 lbs.	90 lbs.	90 lbs.	90 lbs.	90lbs.

To Sir G. Molesworth's *Pocket Book of Engineering Formulæ* we are indebted for the following rules :—

TRACTIVE POWER OF LOCOMOTIVES.

D = Diameter of cylinder in inches.
P = Mean pressure of steam in lbs. per square inch.
L = Length of stroke in inches.
W = Diameter of driving wheel in inches.
T = Tractive force on rails in lbs.

$$\text{or, } T = \frac{D^2 \times P \times L}{W}$$

EFFECTIVE PRESSURE OF STEAM ON PISTON.

With different rates of expansion—Boiler pressure being taken at 100lbs. per square inch.

Steam cut off at	$\frac{3}{4}$	of stroke	= 90	pounds.
"	$\frac{5}{8}$	"	= 80	"
"	$\frac{1}{2}$	"	= 69	"
"	$\frac{1}{3}$	"	= 50	"
"	$\frac{1}{4}$	"	= 40	"

The tractive forces given on the next page for each locomotive mentioned in the Hunslet Company's Table of Dimensions have been carefully calculated from data which their own experience has proved trustworthy. All these engines are capable of exerting the force specified under fair average conditions, and in many cases have developed even greater power. In order to find what loads they are capable of dealing with on any gradient, we give below divisors for different inclines which are the *gross loads in tons the engines will actually haul.*

As no railway is absolutely level and straight, a liberal percentage for inequalities has been allowed in the divisor for "level," but where curves occur on a gradient, allowance should be made for the extra frictional resistance.

Hunslet Engine Company's Table of Gradients and Divisors.

For the level divide the Tractive Force by 18.

For a gradient of	1 in 300,	divide the Tractive Force by	19·5
" "	1 " 250,	" " "	21
" "	1 " 200,	" " "	23·2
" "	1 " 175,	" " "	24·8
" "	1 " 150,	" " "	27
" "	1 " 125,	" " "	30
" "	1 " 100,	" " "	34·4
" "	1 " 95,	" " "	35·5
" "	1 " 90,	" " "	37
" "	1 " 85,	" " "	38·3
" "	1 " 80,	" " "	40
" "	1 " 75,	" " "	42
" "	1 " 70,	" " "	44
" "	1 " 65,	" " "	46·4
" "	1 " 60,	" " "	49·3
" "	1 " 55,	" " "	52·7
" "	1 " 50,	" " "	56·8
" "	1 " 45,	" " "	62
" "	1 " 40,	" " "	68
" "	1 " 35,	" " "	76
" "	1 " 30,	" " "	86·6

For example: Find what load a 14″ cylinder engine—as given in Table of Proportions—will haul, in addition to its own weight, up a gradient of 1 in 125.

Tractive force of this engine, 8,580 pounds.
Divisor for gradient of 1 in 125 = 30.
Then, 8,580 ÷ 30 = 286 tons gross load, minus
weight of engine, 24 tons = 262 tons net.

The above 262 tons is therefore the hauling capacity of the locomotive referred to, on an incline of 1 in 125, at 30 pounds per ton.

We made a digression from our remarks upon the the permanent way, so that the effects of its varied inclines upon locomotives might be explained, and having done this we now return to where we left off.

Immediately after passing the fifth milestone on the road to Bathurst, it was found that a *Cutting* had to be made in the side of a hill, and as the material to be removed was of a diversified nature, special apparatus was employed.

In the most extensive cutting of ancient times, namely, that of the original Suez Canal, the slaves employed upon the works were compelled to use their unaided hands to paddle out the sand and earth, at a loss of 120,000 lives. In the early years of railway construction, spades, pick axes, and wheelbarrows were invariably used, and so they still are when other means are not available. Now, however, modern science has brought to our aid special machines that perform the same kind of work with marvellous rapidity, and of this we have had notable examples of late, the head and front of all having been that of the Manchester Ship Canal.

Here we have a cutting, unequalled in the history of the world, of about 35½ miles in length, involving many serious obstacles, all of which were successfully overcome. As the appliances in this vast undertaking were of the most improved description, we shall endeavour to make them throw light upon all similar operations, including those on the Baratanian line. Some idea of the extent of the cutting may be formed when it is stated that its width is 170 feet at the water level, and 120 feet at the bottom, the intended depth of water having been not less than 26 feet. Besides the excavation for the waterway itself, the earth work extended more or less above the water level until, at one place, for a length of a mile and a half, its total average depth became 55 feet, and at another, 66 feet for a shorter distance.

The total excavation amounted to about 54,000,000

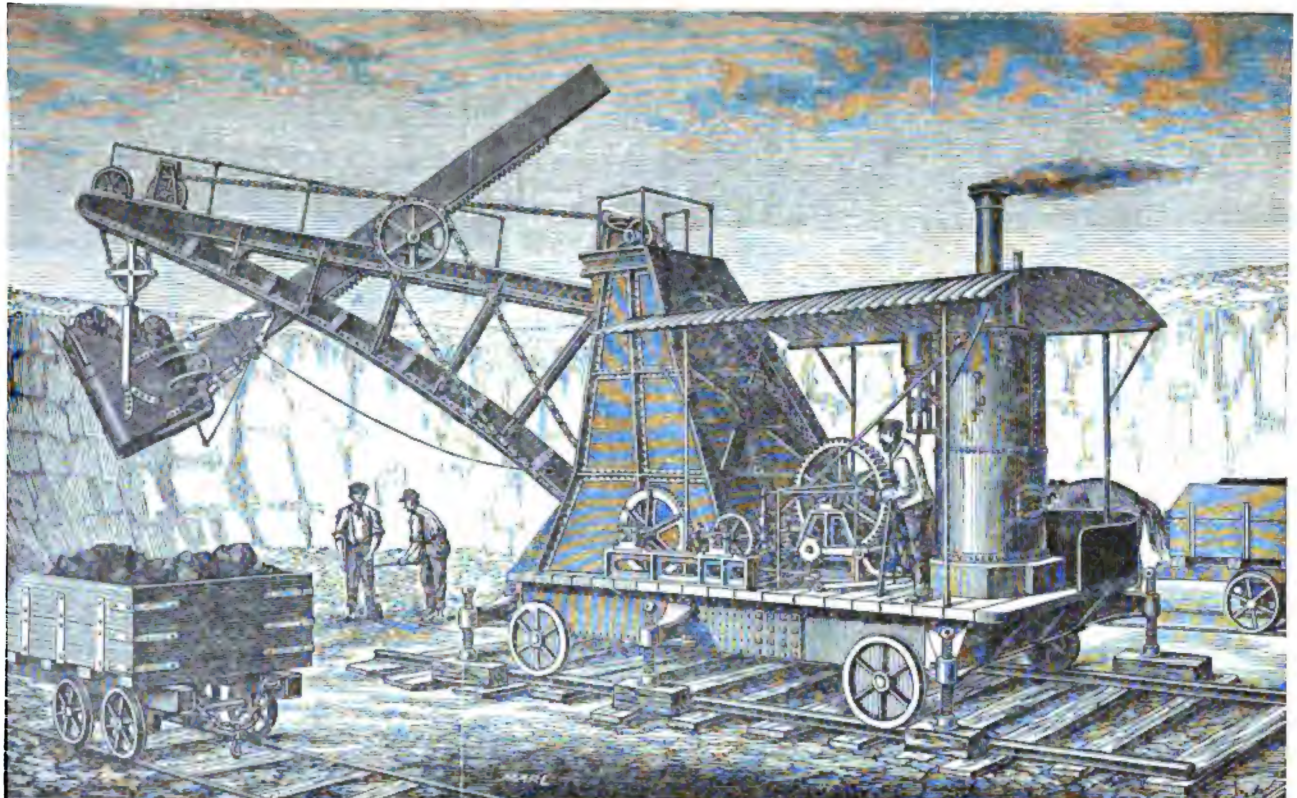
cubic yards of all materials, which may be divided roughly into 12,000,000 yards of hard rock, and 42,000.000 through sand, earth, mud, clay, &c.

During the time the cutting was in progress an average of 10,000 men were employed, but at one period upwards of 16,000 were "on the job," and if these hands had not been aided by the most modern machinery, the work would have been very greatly delayed. Taken in the mass, the appliances included 176 locomotives, 194 steam and other cranes, 209 steam pumps, 241 engines for pile driving and miscellaneous purposes, and 100 *Mechanical Excavators*. This undertaking further required the services of 6,300 wagons, and 223 miles of standard railway, whilst the coal consumption during the period of seven years in which the works were in progress amounted in the aggregate to 720,000 tons.

Most of the above appliances are so well known that no notice need be taken of them. As, however, the *Steam Navvy* is a special engine for excavating purposes, we show opposite an illustration of one by Messrs. Ruston, Proctor & Co., which gives a general idea of the machine, and of its position when at work, its action being as follows:—

The navvy being brought up to the face of the cutting, the bucket is lowered until its arm is in a vertical position. The engine is then started, and the bucket dragged forward and upward into the earth, the depth of the cut being regulated so that it will be full when at the top position as shewn. The jib is next swung round until the bucket is over the wagon, when a cord is pulled which allows the contents to fall into it through the hinged bottom, the same operations being repeated to the end.

On the Manchester Canal 70 of the above were employed, their output in stiff material having been at the



STEAM NAVVY AT WORK ON A CUTTING.

rate of about 1,700 cubic yards per day of ten hours. The power of the above machine is astonishing, as soft sandstone can be removed by its aid without blasting, which is only required when the rock is hard. For sand excavation the buckets are made to hold 2¼ cubic yards, so that two of them will be quite sufficient to fill a large earth wagon without waste at the rate of about 2,000 cubic yards per day, and do the work of from 70 to 80 men in the same time. As the engine progresses, it excavates semicircularly all the material within reach, but it can also be very successfully used for side cutting when required.

The adjacent view of a *Cutting on the above Canal* is very instructive, as it gives a good illustration of recently designed long span and short span bridges in combination. It also shows how simply and compactly a railway deviation can sometimes be made, and most importantly, for this chapter, it exhibits a deep excavation in variegated materials that now forms part of the great waterway.

The old London and North Western line formed, at Latchford, a very serious bar to the construction of the Canal, and therefore it had to be lifted from the level of the cottage on the right of the picture to a point high enough, as shown, to allow ships' masts to pass underneath the bridge. It was additionally placed *alongside* of the old line so that the latter could be used for traffic till the last, the removal of its rails and points to the new position occupying only one day, from 3 a.m. to 7.30 p.m. The cutting was excavated with great speed by means of five of Messrs. Ruston & Proctor's Steam Navvies, the back end of one of which and a small portion of another being seen in the view.

When a railway has to be carried across a depression

CUTTING ON MANCHESTER SHIP CANAL, AND RAILWAY DEVIATION.

of greater or lesser extent, or requires its level to be raised, the system of *Embanking* is generally employed.

The constructive process is simple enough, each wagon load of earth being run along a temporary line of rails, until suddenly stopped by a piece of timber, which causes the wagon to tip on end and discharge its contents over the bank as the work proceeds, the slope being in accordance with the angle of repose of the material employed. Great difficulties have thus been frequently encountered owing to the marshy, peaty, or otherwise unsound nature of the ground over which the embankment had to be carried. In some cases, the materials have either been swallowed up as fast as they were deposited, or the work has been seriously disrupted after construction. The most notable example of the former is to be found in the history of Chat Moss during the progress of the Liverpool and Manchester Railway, which to this day is considered one of George Stephenson's grandest achievements.

As a class of railway work, Embankments are among the most important, ranging as they sometimes do up to those of colossal dimensions. They also permeate in various forms the whole domain of Earthwork Engineering, where ground has to be made up or filled in for general building purposes which cannot otherwise be successfully treated.

CHAPTER VI.

ATLAS WORKS OF MESSRS. SHARP, STEWART & CO., GLASGOW.

Their Origin and Development—Recent Reconstruction—System in Drawing Office—Pattern Shop and its Machinery—The Foundry—Manipulation of Metals before Melting—Treatment of Castings—Forge and its Machinery—Steam Hammer and its Peculiarities—Smithy and its Appliances—Stamping Process—Utilisation of Waste Products—Detail Marking off Department—Gauge and Templet System—Principal Constructive Machines—Various classes of Locomotives—Machinery of a Locomotive—Duplicate Details—Crank Axle Manufacture.

It may sometimes be difficult for people to realise how many things connected with railways they see every day without having the slightest idea of their origin, design, manufacture, or even sometimes their uses. As *Locomotives* form the most prominent portions of the rolling stock, we here intend to describe the various methods employed in their construction at the Atlas Works of Messrs. Sharp, Stewart & Co., of Glasgow, which, for this purpose, we were kindly allowed to visit.

The above firm was founded in the year 1828, at the Globe Works, Manchester, under the title of Sharp, Roberts & Co., who, at that period, devoted their attention chiefly to the manufacture of cotton spinning machinery. In 1830, the opening of the Liverpool and Manchester railway directed the observation of the engineering fraternity to a new sphere of usefulness for their

talents and industry, and amongst those who at once made a special study of the iron horse was the above firm.

A rapidly increasing business necessitated a removal of the whole establishment to the more extensive Atlas Works of the same city, where it was conducted under the title of Sharp Brothers & Co. Subsequently, other changes occurred. The greatest of all, however, took place in 1887, when negotiations were commenced with the Clyde Locomotive Company, of Glasgow, which had only the year before begun operations, with Mr. W. M. Neilson as managing director. This gentleman had formerly conducted his own celebrated Hyde Park Works, in the drawing office of which the writer was very profitably employed for some time. Eventually, the two firms were merged into one, the establishment soon becoming greatly enlarged; and as the old distinguishing title of "Atlas," mentioned above, had become universally famous, it was appropriately retained, whilst the constructive machinery and locomotive branches of engineering were finally carried on under the entire control of Messrs. Sharp, Stewart & Co. Extensions were again made, and the very latest improvements introduced, until the premises became what they were at the time of our visit.

The leading features of design in these Works consist of a one-storey construction of buildings throughout, to save lifting from one floor to another, and also an arrangement of the whole of the departments which allows of continuous progress in the manipulative processes, until the finished work is delivered in the packing shop, connected with sidings leading to the main railways. Here, as in other places, we found the *Drawing Office* the head and front of the whole establishment, since in it are initially concentrated and developed the whole of the resources of

modern theoretical and practical science in design, thus producing the greatest economy in construction and complete success in working.

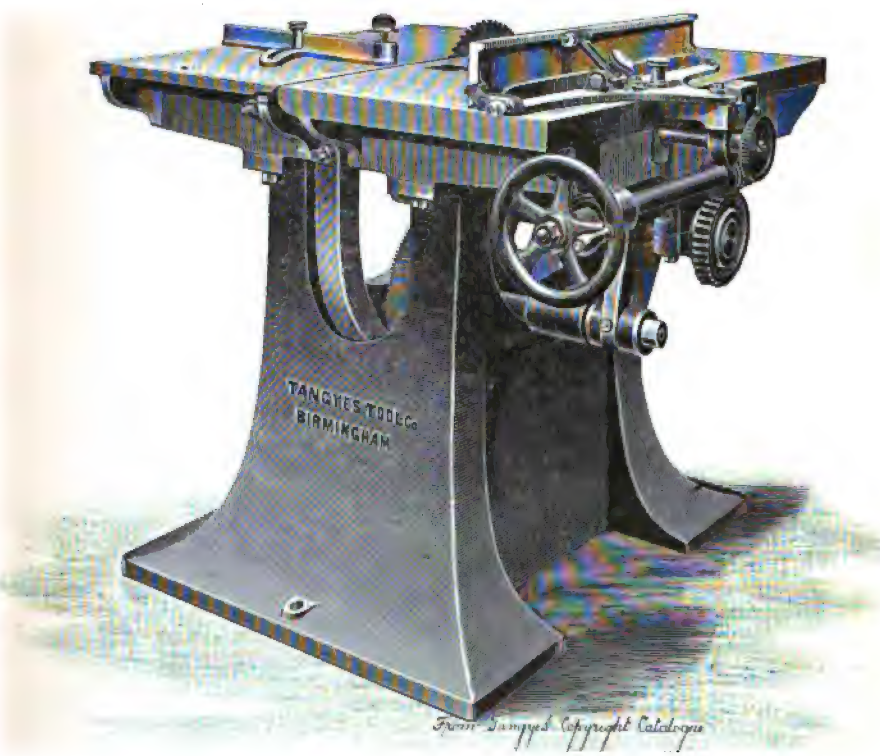
One would naturally suppose that owing to the comparatively small range of size in locomotives, the office work must be much more limited than it is in marine establishments. So continuously varying, however, are the conditions under which railways are worked at home and abroad, that although a few standard designs may appear to be sufficient for the purpose, constant changes have nevertheless to be made in them to suit the views of those in authority on the various lines. Hence, in this spacious and handsome department alone, twenty-six draughtsmen and apprentices are fully occupied. A few young ladies are also employed as tracers.

After the original plans have been fully matured and dimensioned, tracings are taken of them, and when these have been pasted on cloth-backed paper and varnished, they are sent to the various constructive departments to enable the details to be proceeded with.

Passing from this part of the premises, we come to the *Pattern Shop*, containing a copying lathe, band sawing, circular sawing, wood planing, ordinary turning, and drilling and mortising machines, etc., for executing all the work required for locomotive and also for machine patterns of the largest size. In the manufacture of steel engine wheels, the patterns for the arms are first turned in a copying lathe to a tapered oval section, and from these, in a completed state, a casting of an entire wheel is made which combines lightness and elegance with strength.

The *Joiners' Shop* forms part of the above, and here an immense number of patterns are systematically stored for easy access when needed.

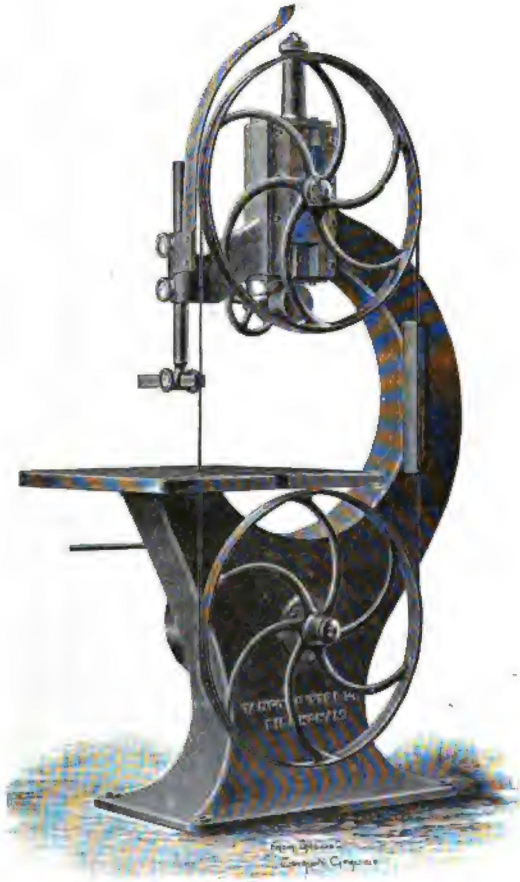
Below we give a view of a special *Dimension Sawing Machine*, by Messrs. Tangye's Machine Tool Co., which is used in pattern making and similar work, and which, while rapidly cutting to accurate measurements, leaves the surface of the wood so smooth that sand-papering



DIMENSION SAWING MACHINE.

only is required to give the necessary finish. The machine is fitted with two saws, one being used for ripping and the other for cross cutting. These saws are on separate spindles, and so arranged that either of them can alternately be brought into play by hand-gear without

touching the driving belt. The ripping fence swivels for bevel cutting, and has a fine screw adjustment, while the cross cut fence is fitted on a sliding table, and has a graduated quadrant for angular work.



BAND SAWING MACHINE.

Another valuable accessory to a pattern shop for irregular work, by the same firm, is the *Band Saw*, one of which, having 30″ wheels, is here shown. The saw

has two guides, one being in the table, and the other above it vertically adjustable to suit wood having a maximum thickness of 14″. The saw wheels are of malleable cast iron for lightness, and covered with indiarubber, the top one of which is carried by a slide vertically regulated by hand wheel to suit different lengths of saws, a coiled spring being used to take up their expansion by heat, the top wheel being also capable of a tilting movement for convenience. When required for frequent and varied bevel cutting, the machine can also be made with a table to work upon a graduated quadrant, which indicates the angles chiefly employed.

In cases of emergency, any sufficiently quick running lathe will do, in a limited sense, for wood turning, but in the systematic operations of a modern pattern shop special machines are employed, one of which, by the same Company, is adjacently shown. Here will be noted the instantaneously setting shifting head spindle and hand rest, and bracket for carrying both, all of which may be put aside when necessary, so that large objects may be faced and turned. To accomplish this, a portable tripod for carrying the hand rest is placed in front, and a face plate of suitable diameter screwed on the spindle so that the wood may be securely fixed to it and operated upon.

Adjoining the pattern shop is the *Brass Foundry*. As, however, there is little to describe in this part of the premises, we pass on to the *Iron Foundry*, which is furnished with all the necessary gear for dealing with the varied castings required for locomotives, and also a portion of those employed in heavy machines. In this, as in all other similar places, the manipulation of the metals for melting is of the utmost importance, as the future success of the castings made from them so much depends

upon the skill here displayed. After the raw material has been carefully selected, the usual process is as follows:—The crude pigs, as they come from the blast furnaces, are recast, and then re-melted if for cylinder and other cast-

PATTERN MAKER'S LATHE.

ings of great strength. For ordinary work, however, the blast furnace products, melted with a certain amount of "scrap," broken up, are quite sufficient.

A *Dressing Shop* is attached to the foundries, so that the

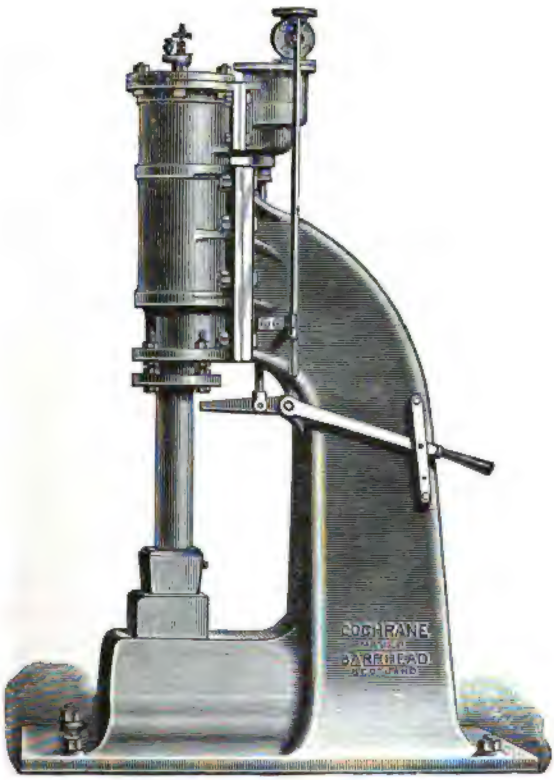
castings may have their surfaces thoroughly cleaned and smoothed before being passed on to the machine departments. The same excellence is initially obtained in those made of steel, but this is partially taken from them by the annealing process. As these castings, when taken from the foundry, would be too hard for manipulation and for future working, they are heated to redness in a special furnace, and then allowed to cool slowly, which softens and toughens them, and renders the discovery of hidden flaws more easy and certain. This metal is now very popular on account of its superior strength and lightness combined, but in constructive machinery, where massiveness is desirable, cast-iron is usually preferred.

As we traversed the premises, we came, next in order, to the *Forge and Smithy*, occupying a large building which supplies all the iron working departments with much that keeps them well occupied.

In the *Forge* all the heavy work is executed with rapidity by the aid of six steam hammers from 12 cwt. to 4 tons. These are chiefly of the single frame type, the extreme popularity of which for ordinary forging purposes may be gathered from the fact that it gives the workman much greater all-round freedom of action than the bridge frame system will allow, the latter, however, becomes indispensable in heavy work owing to its superior rigidity.

The adjacent illustration gives a good idea of the "*Rigby*" *Steam Hammer*, made by Messrs. Cochrane, in various sizes up to three tons, the only differences being in the shape of the piston rod, which is sometimes flattened a little on two sides to keep it from turning, and in the hammer head, which may be either in one piece with the rod, or removable, and also in the anvil and anvil block, either or both of which may be detachable.

These hammers are for forgings of medium size, and, when required, the loose steel anvil piece may be exchanged for stamping blocks of any suitable form. Another feature of this class of machine is that it can be made to suit numerous kinds of repetition work, by



"RIGBY" STEAM HAMMER.

employing additional gear which can instantly change it from a hand worked striker into an automatic forger.

From a theoretical point of view, the force of the blow delivered by any of the above is difficult to determine

with exactness, as the conditions vary so much. It has, however, been ascertained by careful experiments, that the maximum blow of a ½ cwt. double-acting hammer, with moderate steam pressure, produces a crushing effect upon a piece of hot iron as great as that produced by a dead load of about 2½ tons; and a 5 cwt. hammer gives results equivalent to a similar weight of 30 tons, figures which will clearly indicate the power of the engine.

Amongst the advantages to be derived from the use of the improved steam hammer are the following:—

It ensures uniform production of work.

It occupies little space, is easily maintained in working order, and can be manipulated by a boy attendant, whilst by means of its superior power, a forging may be finished at one heat, instead of several, thus effecting a great saving of time and fuel.

The *Smithy* is supplied with nine steam hammers of about 5 cwt. each, two striking hammers for bolts, pins, etc., and various stamping appliances for facilitating the work of forging. In this latter case, the systems most in use are, firstly, one that throws the primary efforts upon the stamper, and the finishing touches of work not to be machined upon the smith. When details, however, have to be turned, planed, etc., it is considered better in many instances, to let the stamping process alone sufficiently rough them out for these operations.

The tyre shrinking on process, which is here carried out, is one of great delicacy, because, if the tyre is not tight enough it is liable to become loose in working, and if too tight, the severe tension upon its cross section may cause it to break during a time of frost, or even from continuous running. To avoid, therefore, the possibility of such a dangerous accident the utmost care is taken by

the turner, and as a further precaution, bolt and ring fastenings are provided.

The machines that perform the turning operations are *Railway Wheel Lathes*, some of which, by Messrs. Sharp, Stewart & Co., are capable of turning a pair of wheels on their own axle at the same time, without torsion, or simultaneously boring two tyres, or turning a wheel or boring a tyre on one face plate, whilst boring or bossing another wheel on the opposite one as may be required.

It may here be stated that the two boilers which supply motive power to the Forge and Smithy portion of the works, are fired entirely by the waste heat from the furnaces. This system is somewhat analogous in its results to that adopted in carriage and wagon establishments, where all the wood refuse cuttings, shavings, etc., are used for boiler firing. These examples clearly illustrate two phases of a system which has for its object the utilisation of waste products, and forms one of the leading features of modern economy now so extensively employed.

It is considered better by engineers, who use enormous quantities of ordinary bolts, nuts and rivets, etc., in their productions, to get them from special manufacturers to keep in stock. We therefore find, as we move onwards, a large *Store Room*, filled not only with a complete assortment of the above fastenings, but a diversified collection of brass, cast-iron, and other standard fittings ready for use.

Continuing our walk, we come to the *Marking off Department*, where all the castings and forgings are first whitewashed, and then laid on truly level iron marking tables where the outlines are scribed upon each, exactly in accordance with the working drawings. After this, the

details are passed on to the machine shop to be variously manipulated to gauges and templets, in order to ensure interchangeability of parts. Here, however, we stand upon the borderland of Practical Science, so advanced, so marvellous to non-professionals, and so fascinating to engineers, that a whole book devoted to this branch alone at the Atlas Works would be much too small if its various subjects were exhaustively treated.

We may, indeed, go further, and say that a modern shop of this nature contains not only many of the most beautiful constructive machines in existence, but those, too, whose present perfection is due to the persistent efforts of numerous talented inventors, whose object has been extreme simplicity, elegance of design, proper proportioning of parts, faultless construction, and the power of producing the best work with the greatest speed, and least amount of wear and tear in the moving parts.

As every "Eminent" well knows, the science of Railway Mechanical Engineering alone is so profoundly learned that even earnest practitioners sometimes need many years to master it thoroughly. Notwithstanding this, we hope to be so clearly intelligible in our treatment of the subject that he or *she* who runs may read, and at least gather ideas which, if required, may be exhaustively developed in other ways.

Upon entering the *Machine Shop* one is immediately struck with the very numerous machines that fill a large portion of a building, 400 feet long by 275 feet in width, which also contains the *Brass Finishing*, the *Boiler Mounting*, and the *Erecting Shops*. The salient features of this part of the premises consist of a thoroughly systematic arrangement of lifting and traversing gear over the whole area, and the introduction of very extensive glazed roofs that admit

a splendid supply of light, thus presenting a striking contrast to old establishments.

In this department the machines are chiefly adapted for details of medium size that can be continuously supplied to them in large quantities, of which, at the outset, the *Brass Finishing Shop* forms an excellent example. Here we have many special turret and other lathes, emery wheels, machines for straightening, centering, screw cutting, polishing, etc., and also for testing plates and bars of all kinds.

The adjoining principal *Machine Shop*, is, however, the head and front of this part of the establishment, as all the engine building portions are entirely dependent upon it for employment. As the drawings for a locomotive and tender are usually made full size, half size, and to 3″ and other scales per foot, and as the former have to be very fully and accurately lined and dimensioned, it follows that the utmost care and skill must be used in their preparation. Even when this is done, opportunities for improvement will show themselves as the work of construction proceeds, until eventually the drawings become so accurate in every respect that a full set of details made from them could be rapidly built up into a complete locomotive ready for running on the line.

The machines that operate upon these details are of the turning, planing, slotting, drilling, milling, screwing, grinding, etc., classes, but so improved by modern innovations as to be capable of performing much that was at one time impossible.

To non-professionals as well as to professionals, a visit to the Atlas Works is most instructive, the former witnessing, perhaps for the first time, a series of operations that are as novel as they are astonishing, whilst the latter gains

much useful information. For our purpose, however, it will be sufficient to refer chiefly to machines of a *specially* locomotive type, and of the most improved description.

The monarch of all these is the *Lathe*, as it is able to drill, bore, and surface, and cut screws, in addition to its own particular work. The continuous action also of its tools, and the unique simplicity of fitting rods, shafts, pins, etc., in position, by its aid, is an invaluable advantage. The varieties and applications of the lathe are almost endless, as it ranges in size from the small foot driven specimens up to those by Messrs. Sharp, Stewart & Co., for great gun and crank-shaft turning, the weight of which is about 120 tons.

The *Planing Machine* ranks next in importance. It was invented by Clement, of London, in 1825, and after passing through many stages of improvement, might have been pronounced perfect were it not for the time unavoidably lost even during the quickest return motion of the table. Various modifications are now employed to obviate this evil by enabling the tools to cut backwards as well as forwards at an equal speed, a double cutting tool being one of the latest and most successful examples.

The varieties of the Planing Machine now in use are, to the uninitiated, almost beyond belief, the sizes ranging from those whose cutting area is two feet in length, by one foot in width and in height, to at least 30′ 0″ by 12′ 0″. Amongst the latter may be classed the colossal productions of the Atlas Works for armour plate planing, whose total weight is about 115 tons, and whose power is sufficient to make four tools simultaneously take cuts in steel 1½″ deep, by ¼″ in thickness. In all these cases, the table driving arrangement consists of a worm diagonally placed so as to gear with the rack above it, instead of the

ordinary rack or screw. An improved feed motion, by Messrs. Robinson & Oldfield, is also beneficially employed. The other branches of the Planer family include Portable machines, Shaping ditto, Boiler Plate Planing, etc., and these are amongst the foundation machines upon which the whole fabric of modern mechanical engineering may be said to rest.

Broadly stated, *Locomotives* are usually termed "outside cylinder," or "inside cylinder" engines, both of which may be constantly seen on the main lines. Each of these classes has special advantages of its own, and may be subdivided into "passenger" engines, "goods" engines, and "mineral" engines, all of which are indispensable in their respective spheres of usefulness. Generally speaking, a passenger outside cylinder express has its piston rods connected directly to a single pair of driving wheels from about 6′ 6″ to 7′ 6″ diameter, or by means of coupling rods to both driving and trailing wheels, the leading wheels being of small size for convenience. Goods and mineral engines, on the other hand, are usually of the six coupled species, so that with wheels of medium size they may be enabled to draw the heaviest loads at low speed.

If any ordinary observer were told that the magnificent engine and tender under review had cost nearly £3,000, it might perhaps be hardly credited until the facts of the case became known, facts too, which indicate the great excellence of the materials used in construction, and the extreme care employed in the manipulation and fitting together of every part individually and collectively. On account of the severe usage to which locomotives are constantly exposed, it is not surprising that railway Companies should insist upon the highest class of materials and workmanship, and the most rigid system of testing

and supervision by constructors and surveyors alike, with the object of avoiding even the possibility of occult imperfections. It will thus be seen that a railway engine is so carefully built throughout that its marvellous powers of endurance under rough treatment are only a natural consequence. For the sake of easy repair, however, if any detail should break during a trip, a spare duplicate, suitable for every engine of that class, can be at once sent from the works of the Company, and fitted in its place without delay.

The idea of modifying the original steam engine to enable it to run upon rails was practically initiated by Trevithick in 1808, but so successfully did Mr. Stephenson, and his son Robert at a later period, develop the design of the locomotive, that its leading features have been more or less maintained in those of the present.

The main portion of the machinery as it now stands, consists of a steel boiler containing a sufficient number of brass or copper tubes to give the required tube heating surface. At one end of this is a copper fire box, having a water space between it and the outer shell to which it is strongly attached by numerous copper stay bolts. To the top of the boiler a steel dome, and also a base piece, are riveted, to the latter of which the safety valves are secured. From the inside of the dome a pipe leads the steam to the smoke box, down the sides of which it is conveyed to the cylinders after being exposed to the heated waste gases from the furnace. The exhaust pipe from the cylinders is also placed inside the smoke box, so that its contents may be discharged up the chimney. In front of the smoke box is a large hinged door, which, when opened, enables the boiler tubes to be cleaned or withdrawn, and on the top of the same is placed a chimney that gives an ornamental as

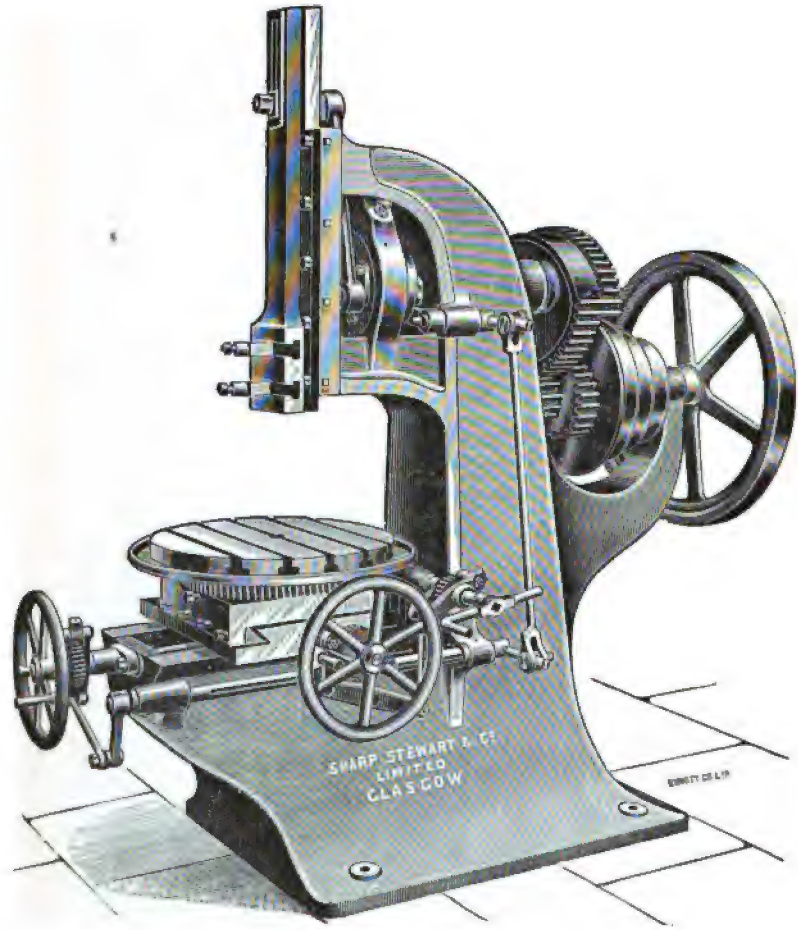
well as useful finish to the structure. On the outside of the boiler are attachments that bind it securely to the framing at the forward end, but leave it free to expand by heat at the after end, and thus avoid destructive strains.

When the axle belonging to a pair of wheels, such as those previously described, has been finished, they are rigidly fixed on it in position. This method of fastening levers, cranks, and wheels on shafts, is a necessity, as they are frequently subjected to very severe and irregular strains which might cause them to become loose in working. To avoid this, however, three processes are commonly employed, that is, ordinary levers are driven on their places; whilst cranks for marine and other engines are shrunk on; railway wheels, on the other hand, are squeezed on by means of the *Hydraulic Wheel Press*, which performs its work with the utmost nicety.

For obvious reasons, straight axles are preferable to cranked ones, but for inside cylinder engines the latter must be employed. When they come from the forge the cranks are solid blocks of steel, having, as well as the bodies of the axles, sufficient extra dimensions to allow for the various machining processes, the first of which is body turning in a special lathe by means of no less than seven tools at one time. The cranks, carefully lined off from the drawing, are now bored at the corners where the future pins will join the intended webs, the intervening block of metal being cut out by the ripping tool of a *Slotting Machine*.

The following engraving of one of the above machines having a 9″ stroke, illustrates their general design and construction as a class, and although the table and its gear are much the same for all up to 24″ stroke, the driving details are made to suit light and heavy work, according

to circumstances. By means of improved elliptical spur wheels a quick return motion is given to the slotting bar, and a practically uniform motion to the tool when cutting.



SLOTTING MACHINE 9″ STROKE.

The ends of the axles are next fitted with temporary cranks that allow them to be suspended in the lathe from

two pairs of centres, the first of which enables the crank pin and the insides of each crank to be turned and faced, and the second pair the curved ends. In each case, however, the face plate of the machine has to be more or less counterbalanced with weights, to enable it to run steadily when so irregularly loaded. After taking off the temporary cranks the axle is again suspended by its original centres, so that the ends may be finished to fit the wheels, and when this is done, the edges of the cranks are planed, and, finally, the wheels are forced on by means of the press previously referred to.

By means of a special *Quartering Machine*, the holes for the outside coupling rod crank pins are now bored in the boss of each wheel at the same time, and the pins fitted to them. This, with the slightly conical turning of the tyres for curve traversing, completes a series of operations which are generally employed in every similar set of wheels and axles.

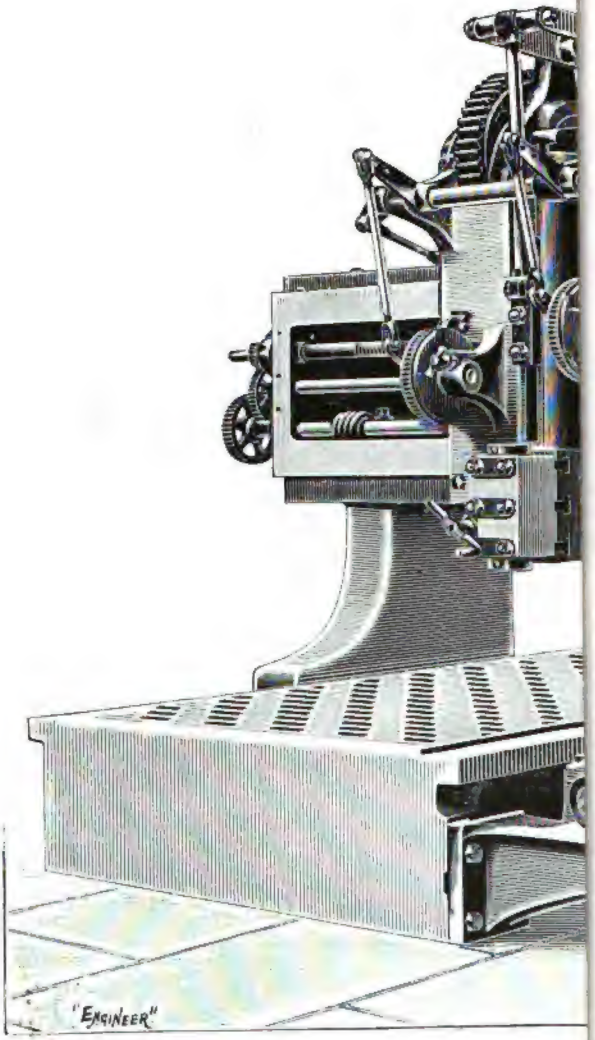
CHAPTER VII.

ATLAS WORKS—GREAT MACHINE SHOP.

Locomotive Frame Plate Construction—Unique Slotting Machine—Duplex Planing Process—Details of Engine Framing—Special Spring Constructive Machine—General Plans of a Passenger Locomotive—Detailed Construction—Cylinder Boring Process—Various Machining Operations—Minor Details—Mr. Joy's Fluid Pressure Reversing Valve Gear—Boiler Design, Construction, and Maintenance—The Fire Box—Strength of Flat Surfaces—General Details of Boiler.

As the outside and peculiarly shaped frame plates of a locomotive form the foundation to which the whole superstructure is secured, we may here describe their manufacture. Firstly, the steel plates of which they are made are rolled at the mills to a thickness of about 1″ for large engines, and then sheared to a rough block outline. By the aid of templets, the exact shape of the finished frame, with its large and small apertures and bolt holes, are scribed on it distinctly to prepare it for what follows.

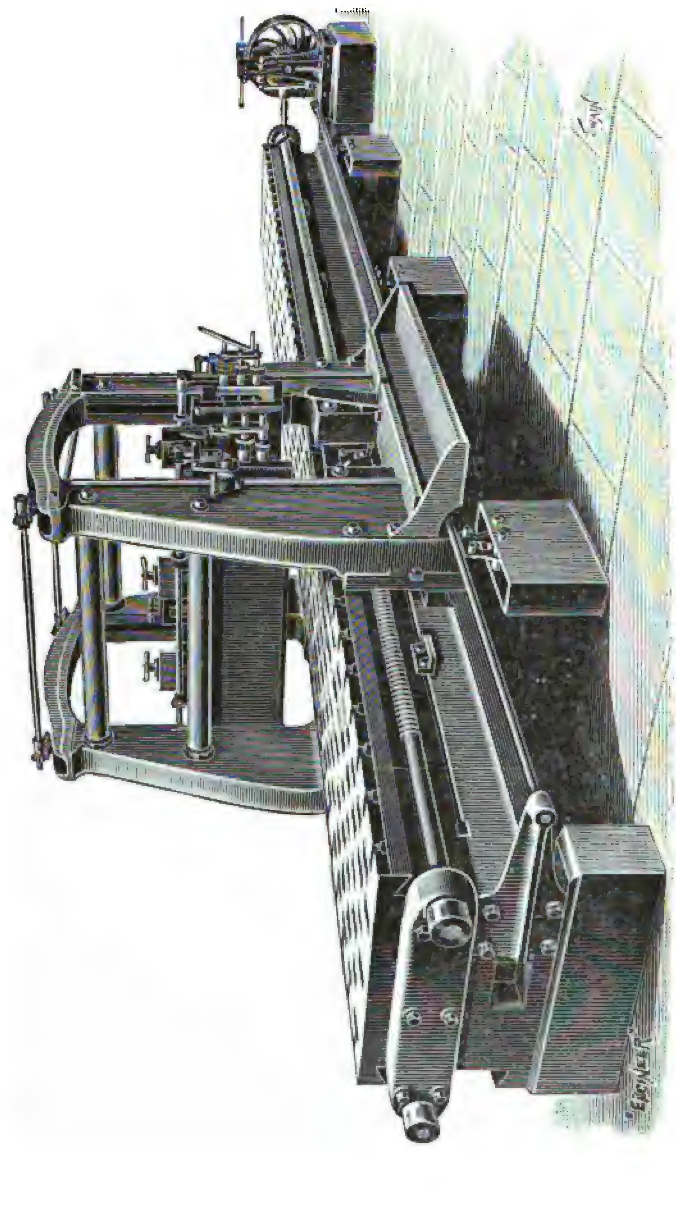
Those who remember the great inconvenience of separating postage stamps before the perforating machine was invented, will fully appreciate the immense advantages of the punching process, which enables operations to be performed upon plates that are otherwise practicable only by means of much unnecessary labour. When the frame plates are marked off as described, their main outline and apertures are thus cut out by a punching machine, producing a roughly approximate configuration of the whole. The next operation is performed by a special


"ENGINEER"

Frame Plate Slotting Machine, by Messrs. Craven Brothers, the table of which is 36 feet in length. This magnificent machine, which is shown in the annexed folding Plate, consists of three slotting heads so connected with the bed plate as to be capable either of independent or of united action, according to circumstances. These beads, with all their gear, are so arranged that a pile of twelve plates can be cut at one setting in parallel, tapered, and curvilinear fashion, to suit the requirements of the engines or tenders for which they are intended.

The above machine is for shaping the edges of the plates as described, but as they also require to be planed on the flat sides, a *Duplex Planing Machine*, by the same makers, capable of planing a surface 30′ 0″ in length by 5′ 0″ in width, is employed for this purpose. The plates are laid on the fixed table, the heads carrying the tool slides being traversed in both directions along it by means of two powerful screws geared together at the back end, where they are simultaneously actuated by the driving gear as shown. Each slide carries two tool holders having six tools, thus making twelve cuts for both strokes of the heads, and, as the above face each other, no time is lost during the return stroke as in ordinary planers. When not employed on frame plates the table may be covered with axle boxes, piston rod guides, etc., thus making the machine generally useful, as indicated by the illustration on next page.

After the *Frame Plates* have been finished in either or both of the above, all the cylinder, cross-stay bracket, horn block, and other bolt holes, are templet drilled to allow for rhymering, so that their tight fitting bolts will bind the whole structure securely together in every part. At the front end, the inside cylinders and buffer beam will form



DUPLEX PLANING MACHINE.

rigid attachments, whilst at the other end, a large casting containing the draw hook gear, and forming a support for the foot plate, will accomplish the same object. Between these two extremities cross-stay plates are fitted, the principal one of which carries one end of the piston rod guide bars and part of the valve gear, etc. If, however, outside cylinders are used, additional stays are put between them to provide the necessary strength.

The bearings of the axles are placed in Axle Boxes, which work in horn block guides firmly bolted to the framing, and clip-stayed at the feet to prevent them from springing, but as the former require a small amount of elastic vertical play, suitable Springs are fitted to them for this purpose. The manufacture of these formerly employed a large amount of manual labour, which has now been greatly reduced by means of a special machine that combines all the processes of shearing, punching, tapering the ends, and slotting and nibbing, thus ensuring rapidity of execution and great accuracy.

For the heavy class of locomotives, such as one of those shown in the following illustrations of Mr. Holden's admirable *Great Eastern Engine*, the body plates of springs are generally made $\frac{1}{2}''$ thick, the top ones, to which the pins are attached, being of special welding steel $\frac{5}{8}''$ in thickness. As the above folding Plates contain such fully delineated views, we shall refer to them in detail as we proceed.

Working drawings of springs are made full size, the exact lengths and breadths of the plates being thus most easily obtained. The plates are tapered and pin hole slotted at the ends to allow for expansion under strain, bent to proper curves, tempered in oil, and then bound together in such a way by a central buckle that every plate is free to slide upon its neighbours under either a steady or

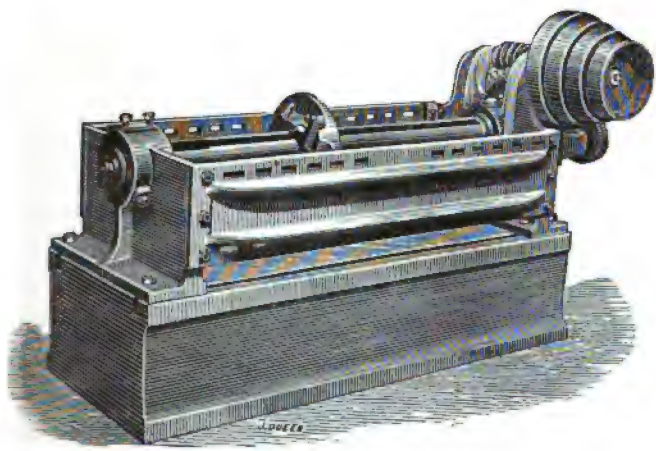
a vibrating load. As every pair of wheels has to bear a certain weight, the proper distribution of these varying loads is obtained by means of adjustable connections between the springs and the framing, which unitedly produce the greatest smoothness in running.

On account of their extreme compactness and convenient application, Volute Springs of tapered plate steel, twisted spirally, are used for buffer and other purposes, and these have proved invaluable. As an engine, however, has sometimes to pull backwards, the jerky shock that would otherwise come upon the draw hook and buffer beam is avoided by means of alternate layers of thick indiarubber and thin iron discs placed behind the latter. It may be added, that for primitive simplicity, and usefulness in various departments of engineering, this spring has, in many cases, never been superseded by modern refinements. Indeed, on the Great Eastern Railway, their supplementary aid to the wheel springs has enabled the latter to wear much longer.

To the forward end of the main framing of engines on English lines is attached a pair of strong plate steel guards for the purpose of pushing any temporary obstruction off the line, thus saving the train perhaps from being derailed. In foreign countries, however, and especially in America, where all sorts of animals get on the line, a powerfully built and triangularly shaped *Cowcatcher frame* is employed, which comes down close enough to the rails for all practical purposes. Here, it is hardly possible for cattle thus to become intruders, but some time ago a bullock trespassed on the North British Railway, and was so crushed by an engine that his flesh and bones, etc., were intertwined in horrible style amongst the machinery. A cowcatcher would have prevented this, and hence the apparatus has

become one of the most ***striking*** and popular features of Transatlantic locomotives.

The *Steam Cylinders* are made of very hard metal, and are bored with the utmost accuracy and glassy smoothness, their valve faces being afterwards similarly planed. The first named operation is performed by means of the *Cylinder Boring Machine*, by Messrs. Sharp, Stewart & Co., shown below, which forms a very simple example of its class, and is illustrative in principle of very many others for



CYLINDER BORING MACHINE.

similar purposes. In this case, the top of the bed plate is filled with bolt holes for securing cylinders up to 20″ diameter upon it, but in addition to this, strong side plates are provided, one of which, on either side, may be used for the same purpose, or both may be removed when a fully unobstructed space is desired.

The boring bar is of the ***hollow*** type, its cutter disc having a feed motion imparted to it by means of an internal screw, the bar itself being actuated by worm wheel

gearing driven by a four-speeded cone, as shown. It may be added that this arrangement is, in modified forms, applied most successfully to machines up to those of the largest dimensions, either vertical or horizontal, the former being preferred for marine work. By this method, not only is a cylinder prepared for its piston with mathematical precision, but its ends are at the same time truly faced for the reception of the covers.

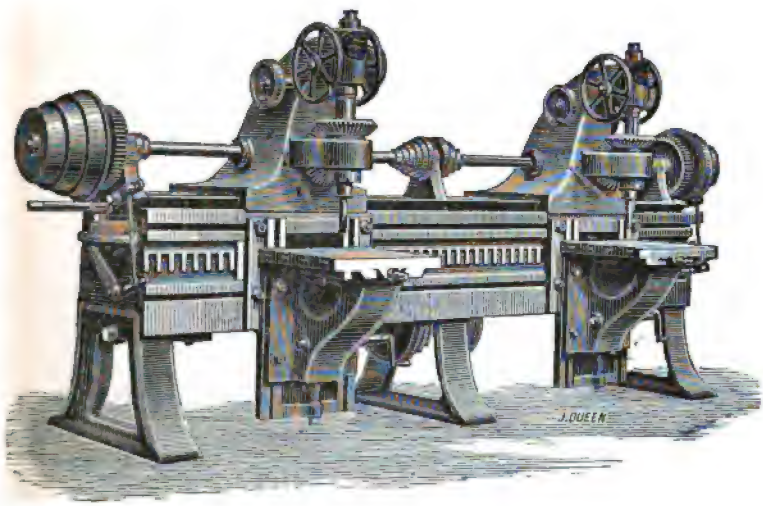
In the *Steam Cylinder* department of an engine there is a great deal of very delicate fitting that, under severe usage on the line, requires little trouble to maintain in good working order, if properly treated from the outset. Perhaps, in this respect, one of the greatest improvements ever made was the introduction of Mr. Ramsbottom's exceedingly simple square steel packing rings for pistons, which have long been employed in locomotives, and also to a large extent in other engines, Messrs. P. R. Jackson & Co. alone having made very many thousands of them.

The *Piston Rods* are fitted with the usual taper to a steel piston at one end, and to a cross-head at the other, which carries the guide blocks, and to which the small end of the *Connecting Rod* is attached. This rod is of flat bar section, with butt and strap extremities; where great compactness, however, is necessary, all slackness through wear at the crosshead end is taken in by means of a very simple wedge block and screw arrangement.

In most locomotives four *Guide Bars* and four *Guide Blocks* are used, but in the Great Eastern engines two specially broad guides and two blocks of the "slipper" description are found sufficient; indeed, the same arrangement has proved most acceptable in very many of the latest marine engines up to as much as 4,000 horse power,

whose get-at-ability of parts, and light-giving space, have thus been greatly improved.

The *Cottar Holes*, in various details that used to be formed by drilling, chipping, and filing, are now executed with great exactness by means of the *Double Headstock Slot Drilling Machine*, by Messrs. Sharp, Stewart & Co., shown below. This machine is additionally employed for cutting key seats, grooves, etc., and for ordinary drilling and boring purposes.



DOUBLE HEADSTOCK SLOT DRILLING MACHINE.

The two headstocks are mounted on a bed 12 feet long, and are independently provided with a very simple automatic reciprocating motion. The length of traverse is capable of being accurately measured by means of a graduated scale; hence, two holes of any required length, depth, and width, or distance apart, may be cut with the utmost nicety, but if too deep to be finished at one setting, they can easily be slot-bored from both sides as with

ordinary drilling. An incidental advantage gained by this process is that the rounded ends of the holes provide greater strength at the point where the *square* corners, due to the hand labour system, were sometimes liable to cause fracture under severe strain.

Coupling Rods are still made of rectangular bars, but for passenger engines the **I** section is preferred, as it combines lightness with strength. As the grooving of the sides has to be cut out of the solid, it must either be done by the planing, or by the milling process, the latter being the best. Messrs. Sharp, Stewart & Co., therefore, provide a machine which, while it completely mills two rods at one time, is also useful for a variety of other work. The ends of these rods are now bored out of the solid, as their specially prepared liners last a long time, and when worn can easily be replaced by new ones.

The *Valve Gear*, if of the ordinary Link motion type shown in Mr. Holden's engine, is too well known to need comment, as it is still very popular. The best appreciated of recent inventions of this nature, however, has been that of Mr. Joy, which does away with eccentrics, and gives such admirable results that he has now supplied it to marine engines of the total power of about 360,000 horses, and additionally, to at least 1,800 locomotives. His latest improvement is the Fluid Pressure Reversing Gear, which has been successfully fitted to many locomotives. This ingenious arrangement consists of two eccentrics, so operated by hydraulic pressure conveyed to their interiors by means of oil forced through holes in the centre of the driving axle, and in the webs and pins of the cranks, as to produce the desired economy and excellence in working. This gear serves all the purposes of the levers, links, etc., which have hitherto been

used, and is devoid of parts subject to wear and tear and requiring renewal.

A unique peculiarity of one portion of the link motion valve gear for locomotives is the solid forging of its levers on the Reversing Shaft. These are necessarily pin-hole bored, and finished to exact angular truth by means of a special horizontal *Boring Machine*, which, however, can be similarly used for tender brake shafts and general work.

The minor details include a thin plate outer framing which extends from the buffer beam to the end of the foot plate, and which carries a narrow platform for enabling the driver or fireman to walk along the sides. This platform carries the *Splashers* or sheet iron casings of the wheels, which prevent the dirt of the line from being thrown about, those for the drivers having sandboxes attached to them, the contents of which enable the wheels to bite the rails when they would otherwise slip.

Having proceeded thus far with our survey of a locomotive, we must now enter upon the consideration of the *Boiler* which provides its motive power, a consideration, too, that has closely engaged the attention of the practical scientists of the present century. So profoundly important is this, that one may well understand the anxiety of engineers to perfect to the utmost the steam raising appendage to machinery. Take the boilers from the most gigantic ocean racer, and she will at once become an inert mass. Try a similar experiment with a locomotive, and its beauty and power will vanish, and so on, throughout the endless systems of transport and manufacture, in which the steam boiler has proved indispensable.

Sixty years of invention and skilled design, and experimental research in connection with the strength of materials, the chemistry of fire and water, and mechanical

construction and management, have been required to bring the steam boiler to its present exalted position, and yet we are not satisfied. Let any lady, or non-professional gentleman, inspect one of the above just finished in the works, and "*Nothing in it!*" will perhaps be the disappointed exclamation. Tell them it will soon be full of water, and fire, and steam, and they may but slightly alter their opinion.

"Can it be possible," they say, "that within the hollow shell that surrounds such commonplace things the talent of at least half a century should have been concentrated? Well!" So it is, nevertheless, as we can abundantly testify.

Before a boiler of any kind can become a success, there are three leading points which have to be carefully considered at the outset, the first of which is *Design*. This will embody all the experience gathered from the records of the past, as well as from the practice of the present, which show how to obtain the highest steam producing power with the least expenditure of material and fuel, and make the boiler most suitable for the work it has to perform.

The second point is *Construction*, and here the accumulated resources of modern science are most effectually utilised, as we hope to show.

The last point is *Maintenance*. This greatly depends upon both of the foregoing, but additionally also, on the manner in which the attendants treat the boiler when placed in charge of it, and which for want of proper care, may rapidly deteriorate or even explode. Under these three heads, then, the whole of the matured practice of the age has now been developed with most excellent results.

The boiler of a locomotive is as simple in design as circumstances will permit, the shell being made strong

enough to withstand a constant working pressure of 140 to 175 lbs. per square inch, and allow at the same time for corrosion. In the Great Eastern engine the boiler shell has a mean diameter of 4′ 3″ by ½″ in thickness, the transversely unstayed barrel of which clearly illustrates the great difference in strength between cylindrical and flat surfaces, such as those in the fire box, which have to be elaborately strengthened.

The wisdom of the early engineers is to some extent shown by the fact that their boilers were plain unstayed cylinders with domed ends, the heat having been applied externally. These ends, however, were superseded by flat ones as the improved Cornish and Lancashire boilers, with internal flues, came into use. Although the hemisphere is now chiefly used for locomotive steam domes, segments of it are frequently employed in many ways, such, for instance, as in the bottoms of large circular tanks for waterworks, whose circumferences rest upon the wall of a tower, thus dispensing with heavy crossbeams underneath. In marine boiler steam chests, too, they are also very popular, and in buckled flooring plates and bridge transverse beams, a modified curvilinear system of construction has proved highly advantageous.

The *Fire Box* is necessarily flat sided, and therefore, as the weakest form of construction, it has to be strengthened all round with screwed and riveted copper stays 1″ diameter and 4″ pitch, the top of the box being stiffened by means of girders of different kinds, and sometimes by direct attachment to the shell of the boiler above it. This box is of copper, ½″ thick all over, except at the tube plate, which is made ⅞″ for tube fastening reasons. The external shell plating is of ½″ steel, between which and the inner box is a 3″ water space, the two being strongly

bound together by the stays mentioned above. At the front of the fire box is the fire door, which is under the convenient control of the attendant, and at its back is the fire bridge, whilst underneath all is the ash pan, whose contents are discharged through a hinged door.

The theoretical consideration of the *Strength of Flat Surfaces* has been attended with so much difficulty that engineers have had to rely chiefly upon experimental information derived from various sources. As an immense number of these surfaces are to be found in locomotive, marine, and other boilers, an accurate knowledge of their resisting power is indispensable, and as their application is now more varied than ever, the difficulty of obtaining trustworthy results has been correspondingly increased. Although the early experiments of Fairbairn in this respect proved of great value for many years, modern practice has shown the necessity for further investigations, some of which have recently been made in England and America.

In locomotives the stays are invariably of copper, with fine threads, so that a better hold may be obtained of a thin plate than with the usual screws. As the plates, into which they are fitted, are of copper and steel, and as the stays themselves are screwed and riveted, it is essential that we should have the most trustworthy experimental data as a basis for calculations.

If we take, for example, a portion of the above fire box, with its stays of the usual 4″ from centre to centre, we shall have many areas each of 16 square inches × 150 lbs. = 2,400 lbs., which represents the tensile strain upon each bolt, and as these are 1″ diameter, they may seem to be unduly strong. The centres given, however, are not determined merely by the pressure upon the plates, as in other boilers, but on account of the possible bulging of the

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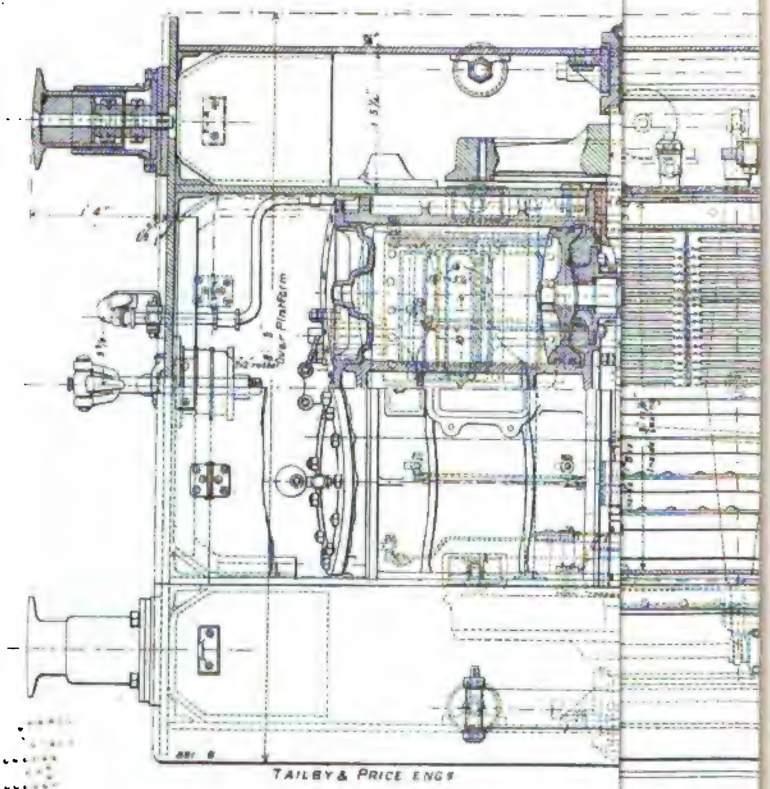

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copper by overheating of its fouled surfaces through the use of bad water, thus indicating one of the numerous "allowances" that have to be made in practice.

As Fairbairn's experiments upon similar surfaces were performed at ordinary atmospheric temperatures, they do not convey any idea of the strength of copper plates when exposed to great heat, and hence, when facts bearing upon this point are understood, the above bolts do not again appear too strong. It has long been known that copper rapidly diminishes in tensile strength with an increase of temperature, some experiments having indicated that 25 per cent. was lost at 500° F., and as this may, from fouling causes, be considerably exceeded, we have a partial explanation of the occasional failures of fire box plates under pressures of 120 to 150 pounds per square inch, after only two or three years' service.

The above experiments were at one time most useful to engineers, as they provided the only practical rules for proportioning stayed surfaces. Now, however, advanced science has given us something better, valuable experiments on a large scale having since been made.

The space between the fire box and smoke box tube plates is filled with the required number of brass, or copper, or steel tubes, not exceeding 2″ external diameter, whose ends are so substantially fixed to them as to form a powerful fore and aft support to both plates. The upper portions, however, of both ends of the boiler are firmly secured by means of longitudinal tie rods.

To the top of the boiler a *Steam Dome* is generally riveted, which contains the *Regulating Valve* for admitting steam to the cylinders, by means of gear placed under the immediate control of the driver. Two *Safety Valves* are also attached.

The *Smoke Box* is what its name implies—a receptacle for smoke and heated gases on their way to the chimney. Engineers have taken advantage of this fact by so placing the steam pipes in the interior of the box, that the boiler tubes can be either cleaned or taken out with ease through its hinged doorway, and also that the pipes may be kept hot without the aid of lagging.

The position of the *Steam and Blast Pipes* is, like all the other details we have mentioned, clearly seen in the sectional elevation of Mr. Holden's engine. To the top of the latter is attached one of Mr. Macallan's variable nozzles, which, by regulating the blast to suit the work to be done, accomplishes a saving of 10 to 15 per cent in fuel.

The *Chimney* that crowns all is too well known to need description. In America, and other countries, however, this appendage is enclosed by a conical casing, covered with wire netting for the purpose of arresting the sparks that otherwise might do mischief. Indeed, immense damage was at one time thus created which the above simple contrivance now effectually prevents.

The *Bogie*, or swivelling arrangement which is placed underneath the smoke box of many locomotives is very useful, as it considerably reduces the rigid wheel base, and this in itself is not only a source of safety but of smooth running on lines having many sharp curves.

CHAPTER VIII.

ATLAS WORKS' BOILER SHOP OPERATIONS.

Manufacture of Steel and Iron—Board of Trade and other Systems of Mechanical Testing—Machines for Testing Purposes—Boiler Testing—Factor of Safety—Limit of Elasticity—Boiler Shop—Boiler Construction—Various Machining Operations—Recent Experiments upon Riveted Joints—Fire Box Details—Tender Construction—Tank Engines—Peculiarities of the Punching and Shearing Machine—Notes and Experiments.

As we have, up to this point, merely referred to some of the leading features of a locomotive, we shall now endeavour to show how it is actually constructed in the works from its initial stages to the finish. Firstly, then, the *Manufacture of Steel*, of which the engine is so largely composed, need not here be described, as that will be done in Chapter XIV.

When, however, *iron* plates, etc., are to be made, the ore is in the first place smelted at the *Blast Furnaces*, and cast into crude "pigs" that vary in quality according to the mineralogical nature of the locality from which it is taken. The next process is termed "*puddling*," or stirring about in a special furnace, by means of which crude cast iron is changed into malleable iron. It is this initial movement that lays the foundation of the vices or virtues of the future rolled or forged material, and produces iron that is absolutely worthless, or of the highest quality, according to the chemical and manipulative skill employed at this point.

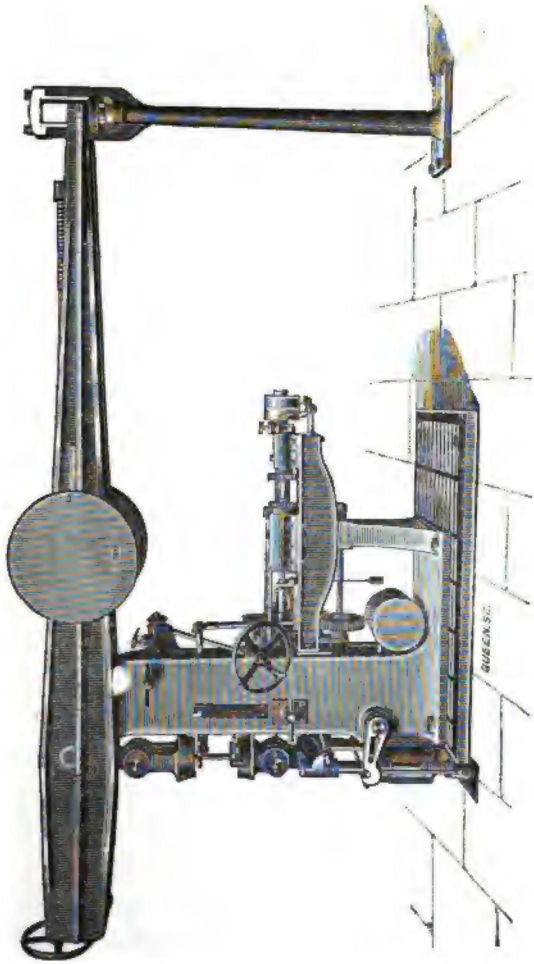
The various changes that occur in the puddling furnace result in the collection at its bottom of a certain amount of plastic metal, which is formed into a ball for convenient removal to an adjacent steam hammer to undergo the "*shingling*" process. By this means, the required "bloom" is prepared for the next operations of cogging, and rolling into finished bars, plates, etc., as previously described.

A test piece cut off each of the above, when it leaves the rolls, as well as the bar or plate to which it belongs, are stamped with consecutive numbers. These samples are then variously tested in accordance with the engineer's specification, and any faulty piece that may be found will cause the rejection of the plate or bar to which it belongs. This, however, seldom happens, as the manufacture of these metals is now so well understood.

What is known as *Mechanical Testing* covers a very wide field, and forms, in fact, the basis of all calculations in connection with engineering structures. To take the practice at the works of the Steel Company of Scotland as an example, it may be said that all orders for plates, bars, rails, tyres, axles, etc., are accompanied by a statement regarding the particular survey they have to pass. Such, for instance, as "The British Admiralty," "The Board of Trade," "Lloyd's Register," "Bureau Veritas," etc. In addition to the above, the engineer's specification of tests in detail will indicate not only their intensity and peculiarities, but the method of applying them in each case.

The tests chiefly used are those for tension, compression, and torsion, and these cover an immense field, their accuracy, however, depends entirely upon the excellence of the system employed in carrying them out, which otherwise might be very misleading. The adjacent view of one of Messrs. Buckton's well known *Testing Machines* for this

purpose gives a good idea of the method of obtaining tensile results, although, at the same time, it may be used, if required, for those of deflection, as well as the others.



BUCKTON TESTING MACHINE.

These machines are variously made to record strains from 5 to 100 tons, and are extensively used in steel works,

ship yards, locomotive establishments, etc. They are all of the single lever and sliding weight type, as shown in the illustration, which has a test piece firmly gripped in position on the left hand side of the framing, and are so manipulated by hand, and also by hydraulic gear, as to be under complete control at every point. Reducing the work of this machine to its simplest form, we may add that, by its assistance, the usual *tensile strength* of 26 to 30 tons per square inch, with an elongation of 20 per cent. in a 10″ length of specimen from each intended boiler shell plate, is sufficiently indicative of its quality in this respect at least, and shows clearly enough at the outset whether the plate may or may not be used.

For *bending test* purposes, a piece is sheared from each plate and bent double in a cold state to a curve, the inner radius of which is 1·5 times the thickness of the plate.

The testing of the boilers themselves, as finished productions, is quite another branch of practice, and requires great care to prevent injurious straining. This last test is almost invariably of a hydraulic description to one and a half times the working load, as failure under water pressure would naturally be harmless. Steam, however, is sometimes employed instead, under, for example, a 180 lbs. pressure for 160 lbs. per square inch in working. To many, such a proceeding will no doubt appear satisfactory enough, as the boiler is thus tested under *working* conditions which the present most admirable system of manufacture will safely allow. Formerly, this was not the case, and hence the hydraulic test was instituted for the purpose of showing whether or not the materials of a boiler had sustained any injury during construction, and also of indicating any leaky joints that might have existed.

Of course, it will be understood, that after all has been

done from a cold test point of view that science can suggest, the application of heat alone in the working state creates severe local straining which has to be considered. Everything, however, is now so fully provided for, from first to last, that the terrible explosions of former years cannot occur.

As the phrase "*Factor of Safety*" is not intelligible enough for everyone, it may here be said that as the working pressure of a boiler must be equal to its bursting pressure divided by a certain number, this number has the above term applied to it. That is, a boiler of any kind whose bursting pressure, for example, is 600 lbs., and working pressure 100 lbs. per square inch, has a factor of safety of 6, which is considered sufficient, but if the boiler is made to the highest standard throughout, a factor of 5, equal to 120 lbs. pressure, may be adopted. These two figures, therefore, thus employed, cover all imperfections that may possibly exist. As the *Limit of Elasticity*, however, for iron and steel may be taken at about half their breaking strength, it follows that, in this respect, the factor of safety becomes 3 instead of 6. Further, the latter figure is constantly changing in general practice, not only on account of the materials and workmanship employed, but owing to the manner in which the former are strained, either by *dynamical* loads, as in machinery in motion, *statical*, as in roofs, and *running*, as in railway bridges, etc., all of which require special treatment. This will be still more apparent, when it is known that in connection with all these the designer has to consider the chemical, atmospheric, and other influences to which his intended structure will be exposed, and also the treatment it may receive from the, perhaps unskilled, hands under whose care it is to be placed.

Now that we have manufactured our plates, and tested them all to the "satisfaction of the engineer," as well as to that of the other scientists, we shall next proceed with their manipulation during the construction of boilers as we found it in the Atlas Works.

The *Boiler Shop* of this establishment consists of a building 162 feet long by 150 feet broad, divided into four bays, the roofs of which are supported by rows of cast iron stanchions of the usual H section, which conveniently carry the overhead travelling crane girders, and various machine attachments, etc. This edifice, although detached from the Plate Bending and Flanging departments, is worked in connection with them, and is supplied throughout with the best machinery for facilitating operations at every stage of manufacture.

In the *Plate Bending and Flanging Shops* are to be found plate and angle iron furnaces, and one frame plate furnace capable of taking in a 30 feet length. A hydraulic press for shaping fire box plates is adjacently located, and, in addition to these, are punching, shearing, angle-iron bending, and other machines. Adjoining this building are four of the largest Lancashire boilers, which provide motive power for nearly all the machinery of the works.

The *Boiler Shop* contains machines such as those for ordinary as well as for radial and pillar drilling, copper fire box drilling, counter sinking, two spindle tube plate boring, three spindle shell plate drilling, plate bending and flattening, plate edge planing of sides and ends at one setting, stay hole screwing, punching and shearing, hydraulic riveting, etc.

One of the bays of this department is occupied with *Tender Construction*, and here there are hot and cold iron

sawing machines, and a variety of other tools and appliances, including a complete system of hydraulic jib and overhead travelling cranes, just as in other parts of the building, and, indeed, throughout the establishment.

There are three places in the Atlas Works which ladies and others, perhaps, might not care to visit, one being the Forge and Smithy, the second the Foundry, and the last the Boiler shop we are now entering. In the former, showers of red hot metal or scoriæ would certainly damage the parade costumes of those who incautiously approached the centre of fire and noise. In the foundry, especially towards evening, the surrounding gloom, and the dangers of miniature volcanic territory created by the presence of a large quantity of melted metal now being poured into the moulds, will deter many from entering too closely upon the scene. In the boiler shop, on the other hand, the noise may often be of a deafening nature, as the hydraulic process has not quite abolished the sometimes more convenient system of hand riveting once so universally employed. So much *real* interest, however, is attached to this department that we cannot avoid describing the scene.

To begin with, then, it may be said that all main boiler plates, upon arrival from the mills, are usually about $\frac{1}{2}''$ longer and broader than the finished dimensions, to allow for planing, and their thickness is to the given standard. As weight calculations, however, enter very largely into all engineering undertakings, these, in the present case, may be easily worked out by allowing, as a basis, 40 pounds per square foot for 1″ iron, and 41 pounds for steel plate of the same thickness; and as these simple figures are also used in a modified form for steel and iron bars of every description, their value will be clearly understood.

After being examined, and re-tested when necessary,

the first thing to be done with the boiler shell plates is to place them in a special planing machine, so that their edges may be trued up and finished to the exact dimensions. If the joints are to be of the butt description, the edges will be made square, but if lap joints are to be employed, an angle of 75° is considered advisable, as it enables them to be more perfectly finished. Formerly, it was the custom to leave the edges of the plates rough, as they came from the shearing machine, the caulking being performed with a thin tool that cut grooves which afterwards greatly exposed the boiler to internally destructive chemical and mechanical action. Now, however, every plate is planed to a slightly bevelled edge, as above, and joint finished with a *thick* tool, thus enabling much better work to be produced than would otherwise be the case. The subsidiary advantages of planing are that it gives an additional proof that the plate is sound, as nearly all imperfections are visible at the edges, and also that a proper finish is given to joints that were at one time supposed to do well enough without it.

Plate Edge Planing Machines are now manufactured by many firms, each of which fancies its own the best. The arrangement adopted at the Atlas Works, however, is one originally designed by Messrs. Campbell, Smart & Co., and extensively used during the erection of the Forth Bridge. Since that time these machines have been made to suit locomotive building, where they are employed in trueing-up a side and an end of each plate at one operation. When the plate is set fair on the table of the machine, it is secured in position either by hand screws, or by hydraulic rams, which are more expeditious. The tool is flat edged, and deep enough to take a *full* cut; and as its speed is the same both ways, its instantaneous reversal gives the

machine the almost continuous action that is so much desired.

The next operation is that of *Bending*, by means of *Plate Bending Rolls*. The top roller is capable of vertical adjustment in such a manner that any desired curvature may be given to the plates as they pass between it and the two lower ones, one of its bearings being so manipulated as to enable conical and cylindrical tubes to be removed endwise. The rollers can also be adapted at one end for angle and tee iron bending if desired.

As plates are liable to become twisted during transit, and therefore require adjustment, they are passed through a *Plate Straightening and Flattening Machine*, that does its work admirably. It will be observed in the view of one of these on next page that there are four rollers in the top row, and three in the lower one, the former being capable of vertical movement to suit plates of varied thickness and irregularity. This illustration also fairly shows the manner in which power is transmitted to the similar rolls of the bending machine just described.

After the plates have been curved to a full circle as described, they are passed on in sets of temporarily secured segments to the *Boiler Shell Drilling Machine*, which enables all the rivet holes in the longitudinal and transverse seams to be bored with great accuracy and rapidity. It will thus be seen that, as the holes are of gun barrel truth, the fitting of the rivets will be perfect, and the adjacent metal uninjured by the drifting which formerly was required to rectify punched apertures.

After the drilling comes the *Riveting*, and here we touch the borders of the hydraulic system that has

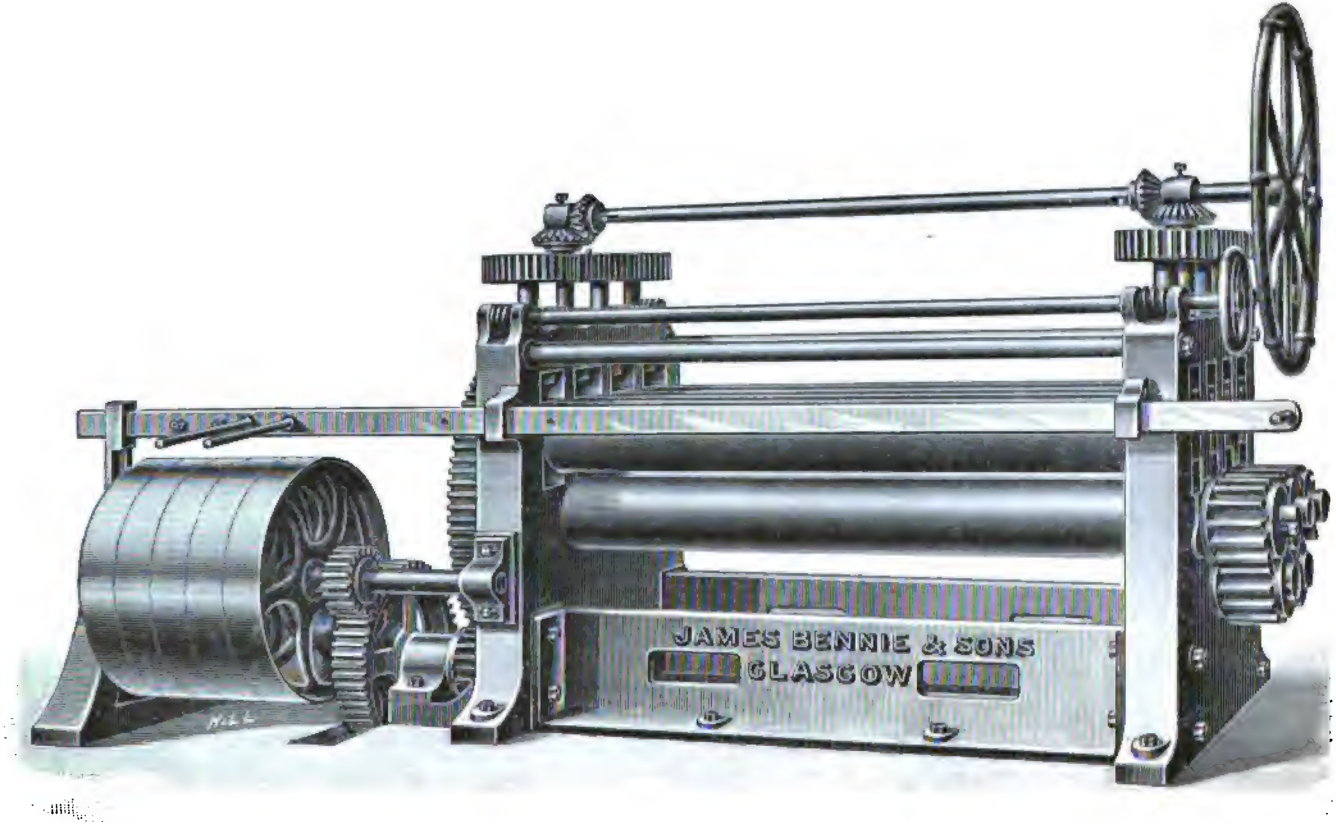


PLATE STRAIGHTENING AND FLATTENING MACHINE.

entirely revolutionised this most important process, and made it a work of solidity unattainable by the old fashioned methods, which are now almost extinct.

The boiler of a locomotive is usually formed of three rings having their joints above the water line, and when these are of the butt description butt strips are placed inside and outside, thus giving, when double riveted, about 76 per cent. of the strength of the solid plate, as proved by a recent series of experiments by Professor A. B. W. Kennedy upon steel plate riveted joints. The general conclusions he came to were as follows:—

For $\frac{3}{8}''$ steel plates, the double riveted lap joint was very nearly as strong as the butt joint, a mean of 75 per cent. having been reached for the former, and 76·6 for the latter.

For $\frac{3}{4}''$ plates, the butt joint was stronger than the lap in the proportion of 75 to 69.5 per cent., whilst with 1″ plates, the butt and lap joints became respectively 76·1 and 70·2. As 76 per cent had previously been considered a good allowance for double riveted $\frac{1}{2}''$ steel locomotive boiler plates, the above experiments indicate clearly enough that it was sufficiently reliable when the best workmanship and materials were employed.

The *External* or *Covering Plate* of the fire box is in one piece throughout, and extends from the foundation ring on one side to the same ring on the other side. As this ring is of solid metal, machined to the exact shape and size, and double riveted to the fire box and its shell so as to form a water space, it makes not only a good fixing for these plates, but a convenient attachment for the *Ash Pan* beneath it.

The *Fire Door Ring* is made solid, as above, by pressing and welding, and, like the other, may be seen in the

sectional elevation of the Great Eastern railway engine so much referred to in these chapters. The driver's eyesight is protected from even the temporary glare of the fire when the door is open by means of a small plate shield, and here we expose a principle in optics not popularly recognised on a useful scale. The steering house of a Mississippi steamer is kept in the most profound darkness by night, simply to allow the pilot to see his course more distinctly. Similarly, a locomotive driver is enabled to do the same thing by means of the shield referred to, and thus accidents may be more easily prevented.

After the proper *Fire Grate* area has been decided on, the grate itself can be easily made by placing two or three cast iron bearers on supports attached to the bottom of the fire box. These bearers carry the wrought iron fire bars, which loosely rest upon them, and are thus free to expand by the great heat to which they are exposed, and easy to remove at any time. They are so spaced as to allow a sufficient supply of air to pass between them, and also the discharge of ashes into the *Ash-pan* below, the front of which is fitted with an air regulating door for the purpose of accelerating or retarding combustion in the furnace.

Very much might here be added to this description of a locomotive, had our object not been to give the reader a general idea of the leading features of the iron horse without going too much into details. And, further, because with such explanations ladies as well as gentlemen may comprehend more easily the engine that moves in and out before them from day to day, and proves so visibly advantageous to everyone.

The *Tender* is the last adjunct of a locomotive to which we shall at present refer, and although it is so simple in

construction, it is much too important to be overlooked. It may be described as a food and water carrier to the engine to which it belongs, and is therefore designed to maintain a requisite supply of both in the most effective and handy manner.

Primarily, the tank is made large enough to hold a supply of water for, say, a 60-mile run, and the ordinary method of obtaining this is by means of water cranes placed at the side of railway station tank houses. As the stoppages for this purpose often occupied too much time, the late Mr. Ramsbottom, the talented Chief Mechanical Engineer to the London and North Western Railway Company, invented an automatic method of filling the tender when a train was at full speed, which was first applied, with excellent results, to the Irish mail during its run of 85 miles between Chester and Holyhead.

To enable the apparatus to be advantageously used, a perfectly level portion of the road was selected, and here, between the rails of each line, an open cast iron water trough, 18″ × 7″, and about 480 yards in length, was fixed. The tenders were next fitted with an internal pipe, the top of which was curved downwards to facilitate the flow of the fluid, the lower end being bolted, not only to the tank bottom, but to a bent pipe outside having a hinged rectangular end capable of being dropped into position at the exact time by simply pulling a lever. To avoid, however, any mistake in raising or lowering the scoop on the part of the driver, which might have created mischief, the rails were raised a few inches above the ordinary level for a suitable distance at each end of the trough, and this effectually prevented accident.

When we retrospectively glance at the various improvements introduced by Mr. Ramsbottom, one cannot but feel

that he was one of those practical scientists some of whose inventions, even to this day, can hardly be superseded by others. Their simplicity and usefulness were powerful recommendations, as may be gathered from the extreme popularity of his steel wire piston rings, and, amongst others, the water supply apparatus just described, from both of which "inventive geniuses" would do well to take hints.

With the object of enabling locomotives to perform useful work on short branch lines, or as shunting engines at ironworks, collieries, docks, mines, and all kinds of great constructional undertakings, the *Tank* engine was introduced. This is not only much more compact than those with tenders, but much less costly. For the above reasons four-wheeled engines are extremely popular. Many, however, have six wheels, but in both cases coupled together as in the ordinary goods engines of the main lines, the tanks being carried either in saddle fashion over the boiler, or at its sides, as illustrated in a later chapter. These two classes of engines are extremely useful to contractors and others in all parts of the world, especially in places where wood fuel can alone be obtained, and for which they can be so easily adapted.

The *Construction of a Tender* runs partly on engine and partly on boiler lines. That is, the framing, wheels, axles, springs, axle boxes, brake gear, etc., are fitted up on engine territory, and with engine exactness, though not with such high finish; whereas the tank, as a boiler shop production, has its plates planed, punched, riveted, etc., by the machinery of this department alone.

As the *Punching and Shearing Machine* is indispensable for very many ordinary plate and bar manipulative operations, Messrs. Craig & Donald have designed one of a

Double-ended Twin Punching class, which is very useful for double riveting and other purposes where speed and great exactness are necessary. This machine is electrically driven, and of the cam and lever description, the punching slides being so arranged as to pause at their highest points for one-half of the cam's revolution, and thus give the attendants a good opportunity for setting the plates accurately previous to the descent of the punches. These may be all of one size at the same time, or of different diameters, or singly instead of duplex, to suit the work in hand. Their pitch may also be varied by means of separate blocks instead of by mechanical adjustment, so that the utmost rigidity is ensured. Further, the machine may be modified in design to enable one end to be employed in shearing operations, overhead bearings being used for carrying the upright of a jib crane for traversing long and heavy plates.

This machine is made in various sizes to suit rivet holes from $\frac{3}{4}''$ to $1\frac{1}{2}''$ diameter, and plate cutting up to $1\frac{1}{2}''$ in thickness. By the application of suitably shaped dies to the slide in front of the machine, large oval and circular holes may be cut out of the thin plates which are sometimes very extensively used when lightness, combined with strength, is desired, or plates may be notched to enable them to fit easily any angle iron or other obstructions that may lie in their path.

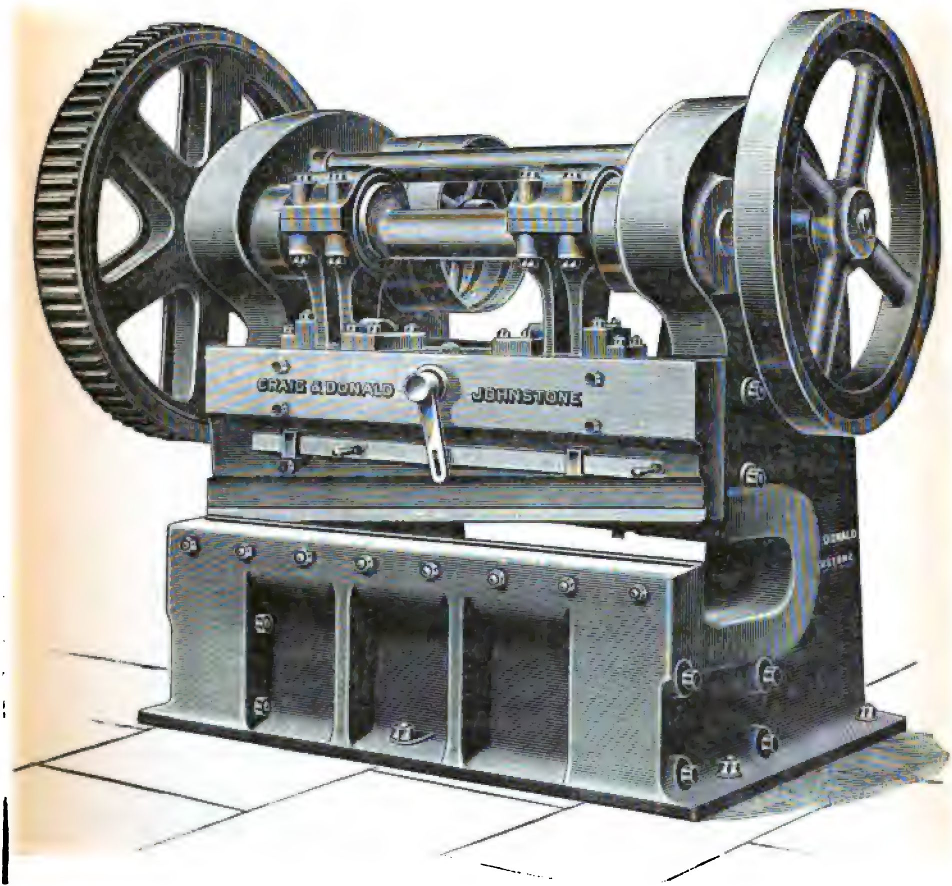
As previously remarked, in boilers the rivet holes are invariably drilled to ensure the best workmanship. With *Tender* tank plates, however, punching is quite sufficient, the operation being performed by means of a *Multiple Punching Machine*, which is capable of perforating, at one stroke, 33 holes $\frac{11}{16}''$ diameter through a $\frac{3}{8}''$ plate, or a larger number of smaller size in thinner plates, and is especially

adapted for tank work. It can also be designed so that shearing slides or flanging blocks can be substituted for punching gear when required.

The Plate on next page illustrates the arrangement of this class of machine when used for Guillotine Shearing purposes, the slide and front of the bed being made to suit. Here the blades may be from 6 feet to 9 feet in length, the thickness of steel plates to be cut from $\frac{1}{2}''$ to $\frac{5}{8}''$, and the length of cut at one stroke, 4′ 6″ to 6′ 6″. It will in this case be clearly visible that the source of motion in these, as well as in all other punching and shearing slides, is the solid forged eccentric on main shaft, which is very convenient. A similar motion is employed at the Shaw's Water Cotton Mill at Greenock, with the object of automatically lifting its 117 ton water wheel sufficiently off its lower bearing brasses, when adjustment is necessary, without the aid of any other lifting appliance.

The safety of all mechanical structures depends very largely upon the manner in which their shearing strains are provided for, and allowances made for irregular conditions of service. For instance, several bolts which sustain a heavy load will individually take their full share of strain if the workmanship is very accurate, but if not so, their united resistance will be more or less reduced. On the other hand, the shearing strength of the well fitted flat link joint pins of suspension bridges will be greatly neutralised unless the pins are made sufficiently large to prevent the crowns of the holes from being crushed. It may also be said that there are many working pin joints in machinery, which, if genteely fined down to theoretical shear proportions would be utterly useless for proper lubrication and good wear. Hence, loosely fitted bolts in structures are relieved of heavy shearing strain by means of supports

that carry all the weight, as in the cross girders of bridges, buildings, etc., and joint pins in shear are made



GUILLOTINE SHEARING MACHINE.

of sufficiently extra diameter to meet every contingency that can possibly arise.

Those who wish to intensify the value of their engineering knowledge should accumulate *full size* data from every

source, as the experiments of the past upon small and perfect specimens gave too high and misleading results, hence, ample allowances had to be made to cover defects in practice. With this in view many most important experiments on a grand scale were made some years ago, and amongst these were a few the object of which was to ascertain the actual Dead Load in tons required to cut bolts in single and double shear, and also to punch holes from ⅛″ to 1″ diameter through iron plates of the same thickness as the diameter of the punch, an abstract from the results of which is given as follows:—

Shearing and Punching Strains.

Diameter of Bolt or Punch.	Actual D.L. Single Shear.	Sg. Stn. per square inch.	Actual D.L. Double Shear.	Sg. Stn. in tons per square inch.	Actual Punching loads in Iron Plates	Sg. Stn. on area of cut surface.
½″	4⅛	19¾	7½	18¼	22	28·0
⅝″	5¾	17½	11	17¼	33½	27·4
¾″	8½	17⅝	16¾	17¾	47¼	27·0
⅞″	12	18½	22¼	17	62¾	26·1
1″	15¼	18	28¼	16¾	80	25·5

An ordinary punch may be regarded as a circular shearing blade whose length is equal to its circumference, and whose whole power must be put forth at once. instead of by the angular, or scissor-like action of a machine shearing blade, which is usually angled from 1 in 8, to about 1 in 12. The shearing strength of good iron or steel is generally allowed to be equal to about four-fifths of their tensile strengths; but in punching a hole out of a solid plate more pressure is needed. Hence we find by the above experiments that the strain per square inch of sheared

area of punched holes ranges from $25\frac{1}{2}$ to 28 tons, instead of 18 to $19\frac{3}{4}$ tons for single, and $16\frac{3}{4}$ to $18\frac{1}{4}$ tons for double shear, as in the bolts.

Suppose, for example, a shearing blade 20″ broad to come down flatly upon a $1\frac{1}{2}''$ plate, it will have to put forth a power of $20'' \times 1\frac{1}{2}$, multiplied by, say, 18 tons $= 540$ tons, before the plate can be severed. If, however, the blade is so angled as to allow 5″ of the plate to be cut through before another 5″ is entered upon, only one-fourth of the above, or 135 tons pressure, will be required to do the work. If, on the other hand, we take a punch having a circumference of 5″, we shall have $5'' \times 1\frac{1}{2}'' \times$ say, $23\frac{1}{2} = 176$ tons, for perforating an iron plate $1\frac{1}{2}''$ thick.

This will clearly show the difference between the circumferential shearing power of a punch when acting upon a plate, and that of a shear blade whilst cutting a bar, or indeed anything else that produces similar strains upon the pin and bolt joints that ramify in every direction the details of machinery. From the above and other experiments, we also discover the enormous resistance of hardened steel to crushing. The mean ultimate crushing resistance of wrought iron is allowed, by the best authorities, to be about 18 tons per square inch, cast iron 43 tons, and wrought steel 26 tons; but when we come to hardened tool steel there is a very great increase, as indicated by the fact that a punch 1″ diameter bears safely a pressure of about 80 tons in iron, and nearly 100 tons in steel plates.

At present punching and shearing machines seem to have reached their ordinary limit with a 2″ punch and 2″ plates; under any circumstances, however, it is not advisable to perforate plates any thicker than the diameter of the punch, and although one of $\frac{7}{8}''$ diameter has actually

pierced a $1\frac{1}{8}''$ iron plate three times in succession, its collapse was threatened at the fourth hole, a pressure of about 78 tons having been brought at each stroke upon the punch, or say, 130 tons per square inch of area, thus clearly indicating how far we may go in such matters without actually breaking down.

In many cases the above machines are made horizontal for convenience in working. They may be belt-driven, engine-driven, or electrically or hydraulically actuated, but whatever the motive power may be, one grand leading principle distinguishes them from other machines of the duplex order, which is, that instead of both ends of the machine operating simultaneously, they can only act *alternately*, thus requiring about half the driving power they would otherwise need, and avoiding loss by inoperative backward strokes such as those of the slotters and planers previously mentioned. It may also be noted that when a punch is used for cutting apertures up to, say, 30″ diameter, or of equivalent oval, in plates from $\frac{1}{2}''$ to 1″ in thickness, the cutting edge is curvilinearly shaped so that the operation may be performed by degrees, as in shearing, and thus additionally save power.

CHAPTER IX.

ATLAS WORKS BOILER MOUNTING AND ENGINE ERECTING SHOPS.

Recently discovered Peculiarities of Copper—Cause of Irregular Decay under similar Conditions of Service—Broughton Copper Company's Tests—Stay Bolts—How Machined—Theoretical Exactness—How Theory holds the Light while Practice does the Work—Engine Erecting—Review of Details on Floor ready for Assembling—Wheel Tyre Shrinking on—Turner's Allowances—Hydraulic Process—How Crank Axle Forgings are Machined—Milling Process—Two Great Systems of Machine Application—Workshop Manipulations—Flexible Shaft Drilling.

WHEN all the chief parts of the tender previously described have been completed, they are ready to be erected in position with a rapidity dependent upon the accuracy of the drawings, the exactness of the fitting, and the arrangement as a whole. The mountings consist of foot boards, hand rails, footsteps, stanchions, lamp bracket, tail rope hangers, and other little odds and ends that may be better understood by actual inspection in combined form on the line than by description.

As the boiler previously mentioned has been, let us suppose, constructionally completed, we may now follow it to the *Boiler Mounting Shop*. Here, another set of operations are at once entered upon, previous to its final erection as one of the main portions of a finished engine. This shop occupies one of the bays of the building, containing the great Machinery Hall of the establishment, and is immediately adjacent to the erecting shop, with which it is most intimately associated.

The mechanical and chemical investigations concerning the properties of various metals have for many years past been so extensive as to throw much light upon what was formerly unknown. In this respect, however, the occult qualities of copper under various conditions, especially those connected with locomotive fire boxes, have only recently become thoroughly understood. So much so, indeed, that if "Alexander the Coppersmith" could arise from the dust of centuries he might well be astonished at what we have now done with the metal that once delighted him.

As Mr. Dean, the Locomotive Superintendent of the Great Western Railway, had discovered considerable variations in the durability of the fire boxes of his engines, which could not be accounted for merely by the differences in the conditions of working, it was decided to test and analyse samples of copper from fire boxes that had run distances of 54,600 to 500,000 miles. Numerous tensile tests were therefore made, and these, aided by the efforts of the analysts, not only showed the strength of each piece of copper, but the number and nature of its ingredients, all of which, in combination, fairly indicated the reason why some fire boxes lasted so much longer than others under similar circumstances. The Broughton Copper Company, of Manchester, also brought their valuable experiences to bear upon this most important subject, some of these having been concerned with fire boxes that had irregularly failed after two, nine, and twenty years service. Stimulated, too, by recent fatally disastrous steam-pipe explosions in steamers, the marine people have made discoveries, which, in conjunction with the above, will probably supply all we wish to know.

As *Copper Stay Bolts* are a frequent source of trouble, and with the view of ascertaining the loss of strength due

to heating to the ordinary working temperature, numerous tests were made with carefully annealed bolts, 1" diameter of screw, and 11 threads per inch; the result being that their mean tensile breaking strength, if screwed the entire length, was 14·8 tons per square inch when cold, and 12·19 when heated to the temperature of 370°, which corresponds with that of 160 pounds steam. With the bolts turned down to the bottom of the screw for the ordinary working length of 3" in the middle, their breaking strengths, cold and hot, as above, were 14·7 and 11·4 tons respectively, whilst those of the plain unscrewed rods, were 14·9 and 11·9 tons. It may be added, that, so far as annealed fire box copper is concerned, the average of 170 tests gave 14·25 tons tensile strength per square inch when cold, with 42 per cent. elongation in a length of 6½", and 51·6 per cent. contraction of area.

Mr. Dean's Paper, as well as Professor W. C. Robert Austen's Report to the Alloys Research Committee, with tables and discussions, are given in the *Proceedings of the Institution of Mechanical Engineers* for April, 1893, and although here only passingly referred to, are nevertheless valuable contributions to practical science.

As such an enormous quantity of fire box stay bolts are used up in locomotive establishments, it is necessary that some system should be adopted which will enable them to be expeditiously manufactured. To secure this end, four special machines are employed, the first being a circular saw for cutting the copper rods to the exact length. These pieces are next placed between three straightening rolls which true them up. They are then centred at each end by a machine that performs the work with great accuracy and rapidity. After being thus centred, the ends of the stay bolts are milled square in another machine so that

they may be firmly held whilst being screw cut in a chasing lathe, and then screwed into their places in the fire box by hand, the holes being tapped by means of a very simple portable rope driven apparatus. Finally, the ends are rivetted to ensure greater strength.

The boiler mountings previously referred to, comprising safety valves, feed valves, etc., are bolted to wrought iron bases equal in thickness to the depth of the lagging. These form most useful attachments, as their joints are so easily made steam tight by scraping that boiled oil alone may be used, instead of red lead, as formerly was the case when the barbarous custom of jointing direct to the boiler plates was in use. Further, all the parts are now made interchangeable, so that they can be easily applied to any engine of the same class on the line without delay.

After the boilers and their attachments have been hydraulically tested to about 200 pounds per square inch, they are removed to the *Erecting Shop*. Here, however, we shall leave them for the present and endeavour to show how the engine is built up ready for the line.

Let us now suppose that we have waded through the preliminary processes of design and detail construction in the Engine and Boiler departments; that every drawing has been faultlessly correct; that every part has been machined and fitted up to various gauges and templets, and that they are now lying about on both sides of one of the pits of the Erecting Shop, ready for building into a complete locomotive. Although the manipulative accuracy in construction just mentioned is very necessary, merely *theoretical* exactness in design is by no means desirable. Up to a certain point, theory and practice are inseparable, but beyond this, practice alone must be trusted to, as there are many occult causes that might produce disastrous failure

and fracture, if not skilfully guarded against, and ample "allowances" made to cover all the severely irregular strains that arise in working. Theory, sure enough, holds the light, but Practice does the work, and when we reflect upon the performances of the early engineers by the sole aid of the latter, the above remark certainly seems appropriate.

The pits referred to are trough-like excavations extending nearly the whole length of the building, and having brick-lined sides and bottom, their depth being sufficient to enable the shop hands to work comfortably underneath the engines as the latter stand on the rails.

The Atlas Works Erecting Shop is spacious, lofty, and, like the other departments, well lighted from the roof. It is traversed by two 30-ton overhead travelling cranes, whilst numerous hydraulic jib cranes of a very compact and handy class are conveniently placed throughout the shop, down whose sides rows of vice benches are placed for the use of the fitters.

The process of *Engine Building* is as follows:—Firstly, the *Frame Plates* are brought in from the heavy machine shop, the edges of their horn block portions being squared up, and the blocks which guide the axle boxes of the axle bearings bolted on. After this is done, the frames are placed in their proper position on trestles over a pit. The cylinders, guide bars, foot plate, etc, are then accurately fixed, and the boiler lowered into its place, the wheels, axles, springs, and all minor gear being simultaneously added until the engine is ready for trial under steam.

Let us now suppose that all these details are lying on the floor around us in a finished state, and that we are surveying them previous to their being crowded out of view in the built up engine. In the first place, then, let us take

the *Main Frames*, which evidence to this day the talent of the late Mr. C. F. Beyer, who introduced the single plate system, and thus abolished the cumbrous timber and iron framing that was once so popular. These frames have not only been slotted to the correct shape, as previously described, but planed up also on the sides to enable their various attachments to be bedded with solidity upon them. All the bolt and rivet holes, too, have been bored to templet; here, however, we touch the borders of a beautifully simple system which permeates the whole domain of mechanical engineering in countless forms.

In all engines there are very many parts, such as pipe flanges, cylinder, valve casing, and other covers, etc., that are faultlessly fixed by means of loose fitting bolts or studs. Other details which have severe dislocating strains thrown upon them require to be secured with extra care, otherwise dangerous slackness would result. The holes, therefore, in the parts that have to be bolted to the framing, as well as in the latter itself, are drilled a little less in diameter than the finished sizes, and then rhymered after the complete gear has been temporarily fixed in position for the purpose. This process not only insures perfect truth, and a smooth interior of aperture, but such absolute exactness of size as to render every bolt interchangeable throughout every set of engines made from the same plans. When the bolts are turned to gauge, tightly driven home, and their nuts screwed hard up, a rock-like solidity of structure is produced, which, nevertheless, allows of easy disconnection at any time. There is, therefore, no method of binding details together equal to this for elegance, simplicity, and efficiency combined, as every bolt takes its full share of the *shearing* as well as of the transverse strains that may come upon them in working.

As the Frame Plates before us have their horn blocks and other primary parts secured in position, they present a handsome appearance. Messrs. Craven's machines have done their work well, and here, we may observe, that although slotting machines as a class can automatically cut every kind of partial circle, they can also cut parabolic and other irregular curves, etc, by means of one of the rectilinear self-acting motions, aided by a simultaneous hand traverse of the other. In the lathe and planing machine, a similar method is frequently adopted with excellent results.

The cast steel *Wheels*, with which the above plates are so closely associated, have their arms of an elegant elliptical section, the bosses or naves being elongated in plan to form the outside cranks.

The *Crank-pin holes* have already been bored in dead true position, by means of a Quartering machine, and after having been case-hardened and ground to a glassy surface at the bearings, the pins themselves are forced into their places by hydraulic pressure. Similarly, the crank boss of the wheel, after being well lubricated with oil, is squeezed on to the axle with an end pressure of about 12 tons for every inch of diameter of the eye. The great advantages of this system comprise the absence of heating, which is so essential for the shrinking on process, and a knowledge of the *exact amount of tightness* of the fitted parts, which is indicated by the hydraulic gauge, a tightness, too, which, by some is considered sufficient to enable keys to be dispensed with. For marine and stationary engines the other method is preferred for convenience; here, however, we have to trust entirely to the skill of the turner who is by no means infallible.

Wheel Tyres are usually shrunk on their places, the

turner's allowance being in some instances No. 19 Birmingham Wire Gauge for a tyre 4ft. diameter inside, No. 18 for 5ft., and No. 17 for 6ft. diameter.

This question of shrinkage allowance becomes a very serious one when it is known that, while on the one hand cranks and tyres have become loose on their seats when made too easy at first, on the other hand, they have sometimes broken when too tightly fitted. The strain thus thrown upon the section of the metal may be to many beyond belief, but there it is or fracture would not occur. Take, for instance, a steel crank for marine engines, whose usual safe allowance for shrinkage is—

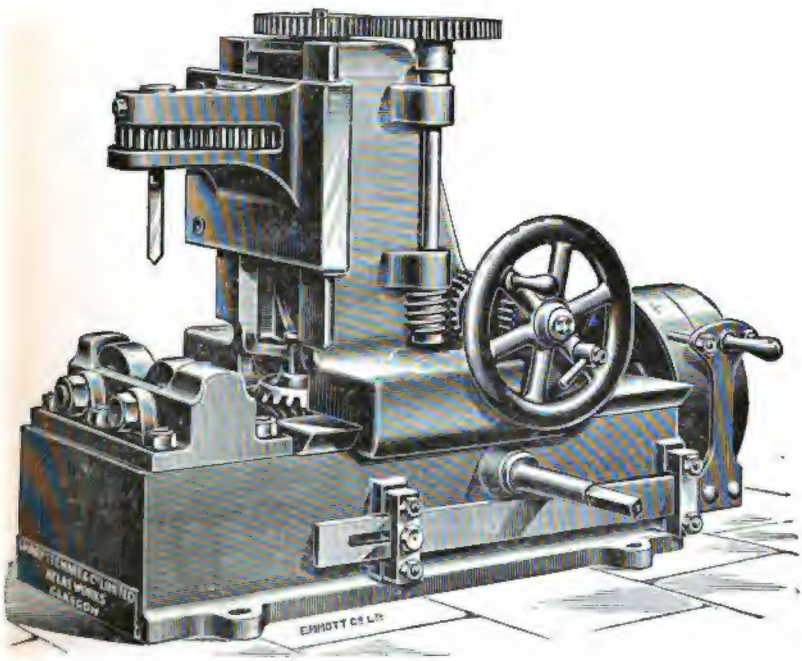
Diameter of Eye ÷ 500 to 750.

Now, if through accident, the eye of the crank should be bored too small, it is possible that it may snap when cooled down from red heat on the shaft, and if, for example, the 30 ton metal on one side of the eye is 20″ by 9″, or 180 square inches in area, a tensional breaking strain of 5,400 tons will be the result; thus clearly indicating the irresistible force of heat and cold combined, which, within such a very small compass, and in many other ways, has been most beneficially employed.

Hydraulic pressure has been used very successfully for tyre fixing, practice having shown that if the internal diameter of the tyre is diminished by one thousandth of the diameter of the rim on which it is to be fitted, its gripping power will be ample. With this in view, a pressure of 20 tons per foot of diameter will do what is needed, a 200 ton press being powerful enough for even the very largest wheels that are made.

In addition to the above process, circumferential wheel clips are used as a safeguard, set pins also are at intervals screwed into the rim and tyre to bind them still more

securely together. As these holes can be bored and screwed only from the inside of the rim by a special machine, we give below an illustration of one made for this purpose, which does what is required with its drill head placed beween the arms of a wheel which rests upon the rollers in front.



TYRE DRILLING MACHINE.

As the unbalanced positions of the cranks on their axles, and also the large ends of the connecting rods would, if unaided, produce a jerky motion, a remedy must be employed. This consists in casting on the interior of the rims a mass of metal as a counter-balancing weight,

which produces smooth and regular movements in the wheels even when running at their highest velocity. The above remarks will, we hope, sufficiently indicate the extreme precautions adopted by engineers in the manipulation of this detail alone, with the object of avoiding to the utmost a repetition of the appalling disasters that sometimes happened when a tyre was fractured through working loose, or snapping during a time of frost.

Next in order to the wheels are the *Crank Axles*, upon which all the metallurgical and mechanical resources of modern times have been pretty well exhausted. As steel is now so trustworthy in every respect, it is always employed in the finished axles whose improved system of machining may here be described.

When the block forgings arrive from the Steel Company, they are manipulated by one or other of two distinct systems, the newer of which presents a striking contrast to the old method. In the former case, the body parts are turned in the usual way, but with several tools in action at the same time, the outside of the cranks being faced up simultaneously. The axle is then hung between the centres of, say, a 3′ 6″ diameter *Disc Machine*, having 36 tools, all of which are set so as to unitedly cut the complete inside width between the cranks out of the solid metal.

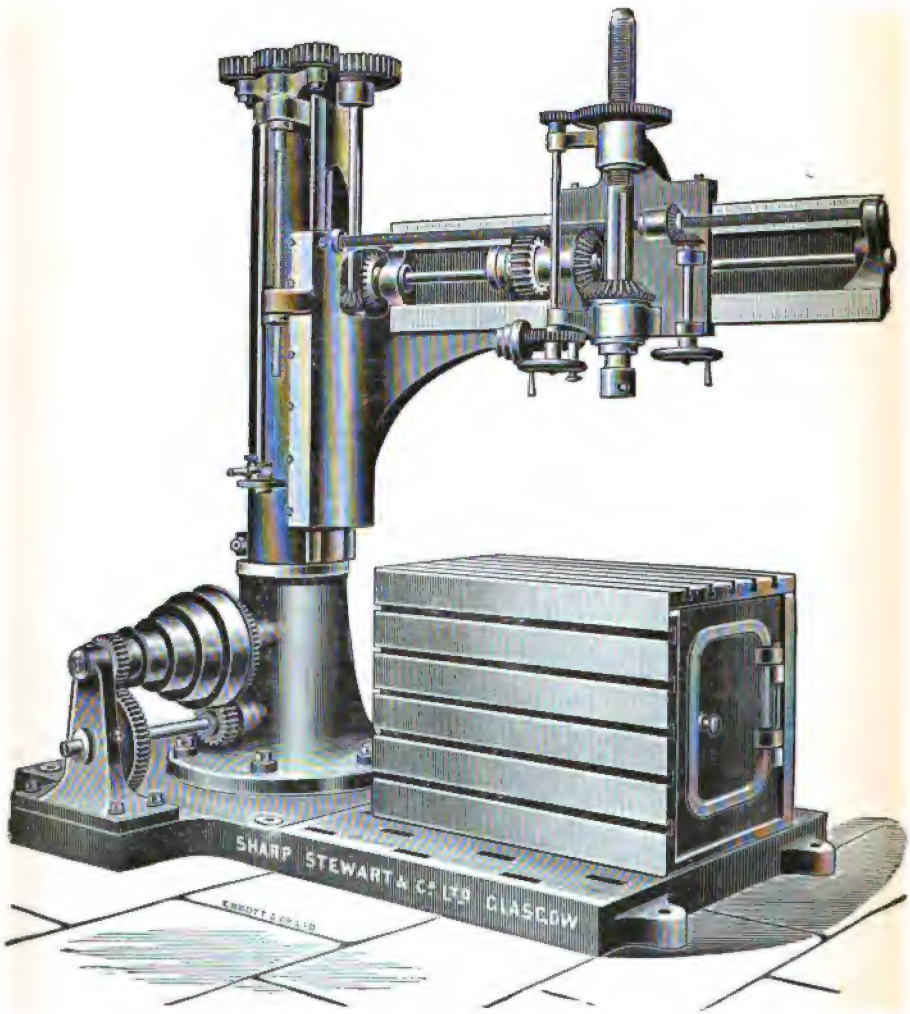
This is done most effectively upon the milling principle, until the cutters have almost reached the inner side of the proposed pin. By means of a special arrangement the pin is now roughly formed by the continued action of the above tools, the finishing touches being subsequently executed by means of a hollow lathe, whilst the edges and ends of the cranks are planed and turned in the usual way. Although this system is adopted in various places, the old method, improved in arrangement, is still popular, the altered gear

of an ordinary lathe producing an acceleration of speed during part of a revolution, and thus saving very much of the time that used to be wasted through intermittent cutting as the cranks revolved between the centres, the lathe when not thus employed being suited for ordinary work.

These two methods clearly exemplify the difference between wholly special and partly special machines, which, to some, may appear perplexing. In places such as the Crewe Works, where all the engines for a vast railway system are made and repaired, *wholly* special machines are constantly occupied upon the class of work for which they were intended. Piston rods being turned in one machine, slide valves planed in another, and so on continuously, thus rendering loss from want of employment almost impossible. In less steadily occupied establishments, however, machines which can be easily changed from one set of operations to another are invaluable. With this in view, the advantages of each system will be clearly apparent.

Amongst the appliances of an all round nature, may be mentioned the *Radial Drilling Machine*, whose usefulness may be gathered from the fact that when a heavy casting is once set on its table, or on trestles, or even on the ground, every hole in it can be bored, faced, drilled, and screwed until the finish, thus saving much time. When required, the arm can be made to swivel, and the boring head to do the same, so that holes may be bored to any angle.

In the following Plate we give a view of one of these machines which pretty clearly explains itself. It may be added, however, that for ordinary work the table is quite sufficient, but for large and heavy details this can be removed, and the base plate used instead. The radial arm



RADIAL DRILLING MACHINE.

swings through an almost complete circle, and can be raised or lowered with great ease, the $3\frac{1}{4}''$ diameter spindle being capable either of drilling holes up to $4''$ diameter,

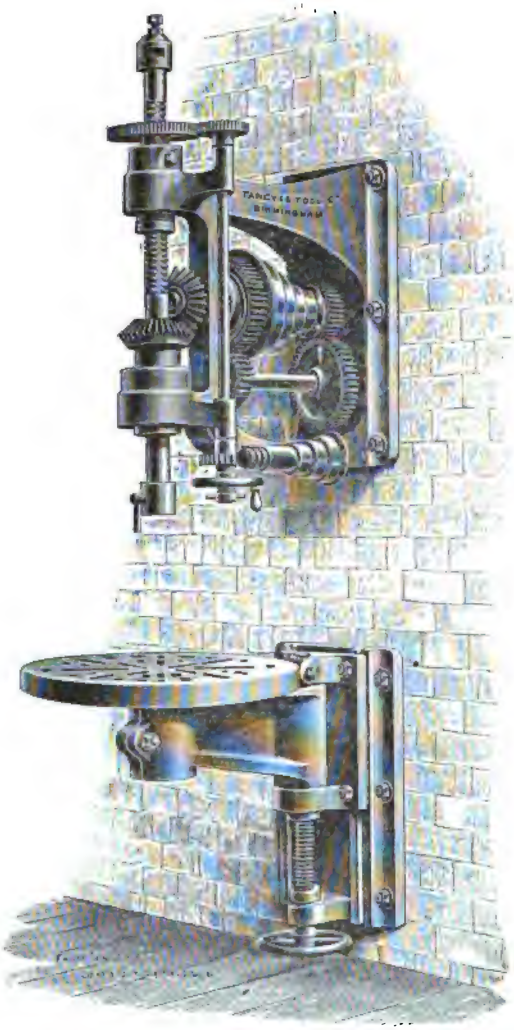
or of boring them up to 12" diameter by means of a cutter bar and boring block. When used for screwing purposes, disengaging gear is employed which prevents the possibility of fracture of the taps through severe irregular straining. Several kinds of this machine are made, including those for swinging on pillars or on walls, which are valuable additions to a workshop.

The view on next page of a fixed *Wall Drilling Machine* shows, in one respect at least, how this is accomplished. Here, the diameter of spindle is $2\frac{1}{2}$"—its vertical traverse 12"—distance from centre of spindle to wall 28"—diameter of table 30", and rise and fall of the latter $10\frac{1}{2}$", locking gear being supplied for fixing it in any position.

With the crank axles before us in a finished state, it may be noted that the key beds for the *Eccentrics* have been cut in them by a small *Portable Key Bed Grooving Machine.* The positions of these are so exactly given by templet, that when the valve gear is all up it will work with faultless precision. This appliance is very useful for a variety of similar purposes, as it saves much unnecessary labour.

The *Eccentric Straps* may be of wrought iron or steel, lined with white metal, or of brass, or even of cast iron altogether, but in any case they are bored and faced in the lathe to the exact dimensions, the adjustable liners between the joints allowing all future slackness from wear to be easily rectified.

The *Connecting Rod* Brasses are scraped with a ground half round file so as to bed truly on the crank pins, the same operation being performed on the brasses of the axle boxes for all the wheels. The latter, when ready for erection are placed at a correct distance apart on the rails of the pits, the so far completed frame portion of the engine

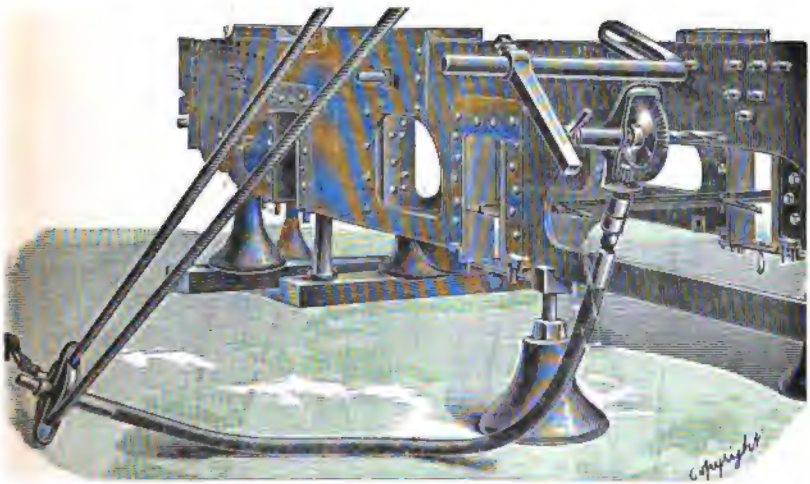


WALL DRILLING MACHINE.

previously referred to being now lifted by two cranes into position upon them. After this is accomplished, the

pistons, rods, valve gear, etc., are fitted up from the pit underneath, whilst all kinds of tools most efficiently aid the work at every point. Amongst these may be mentioned the *Stow Flexible Shaft* apparatus, which is easily applied under circumstances where any other would be inadmissible.

Several arrangements of this gear are in use, one of the best being the *Flexible Shaft and Electric Motor combined.* This little machine can also be used with rope gear for



SLOW FLEXIBLE SHAFT DRILLING MACHINE.

rhymering and screwing purposes, and for drilling holes, as shown in the annexed view.

Between ordinary railway carriage springs and the *Driving Wheel Springs* of a locomotive, there is a very great difference, a difference, too, that is mainly caused by the extremely varied circumstances that arise in practice. Perhaps there is no mechanical detail with which people generally are so familiar as the wonderfully popular laminated or plate coach spring, whose object is to neutralize the

effects of sudden shocks to vehicles of all kinds, especially on railways where, otherwise, much damage would be inflicted upon passengers, the rolling stock, and also the permanent way.

Springs, as a class, comprise those of the volute or spiral plate—the spiral of round or square wire or rod—the laminated—and the combined india-rubber disc and circular plate descriptions. The three latter of which are distinctly shown in our sectional elevation of the G. E. R. engine, in connection with the safety valves, wheels, buffers, and draw hook. The steel of which they are made has a maximum tensile breaking strength of about 32 tons per square inch, the similar strengths of other qualities of the same metal being as follows :—

Cast Steel for Tools	60	tons per square in.
Whitworth Fluid Compressed Steel	68	
Steel Wire	90 to 154	

The last named being the special material used for wire ropes, the enormous strength of which is due not only to the very high quality of the metal employed in their manufacture, but also to its being *cold* drawn through graduated apertures in hardened steel plates until reduced to the required diameter.

Spring calculations have been given in so many text books that nothing more need be said about them. It may be mentioned, however, that in the works, where every finished spring is tested for elasticity, etc., tabulated records of each class are kept for reference. These alone are conclusive to engineers, and save much time and trouble in the drawing office.

CHAPTER X.

ATLAS WORKS' LOCOMOTIVE BUILDING AND FINISHING.

South Kensington Specimens of Past and Present Engines—Design and Workmanship of Modern Machinery—Steam Cylinder Design and Construction—Shoe Block Piston Rod Guides—Valve Gear—Injecter for Boiler Feeding—Final Operations in Building—"Record Breaking" Performance in Erecting—Table of Leading Particulars of a Passenger Engine—Machine Construction at the Atlas Works—How a Crush of Work was overcome—Wheel Teeth Cutting out of the Solid—Their amended Design—Weight Transportation Appliances.

CONTINUING our survey of the details of a locomotive, we come in due course to the *Steam Cylinders*, which have quite a history of their own, as may be noted in the most convincing manner at the South Kensington Museum, where some of the earliest engines may be compared with the adjacent and highly finished specimens of the present time.

As one meanders through the the spacious halls of that eminently instructive Institution and realises the events of the past, there is much to be learnt of a far reaching nature. Some of the most primitive specimens are Watt's first Sun and Planet pumping engine, of 1788, and also Stephenson's famous "Rocket," of 1829, as well as others of that period, and although the former is a study of the rudest possible construction, it nevertheless contains the originals of many of the most beautiful and important details now in use.

The cylinders of all these engines are remarkable for roughness, the pistons being fitted with hemp packing, which could adjust itself to the internal irregularities of

their merely holystoned surfaces. The joints were chipped, thick red lead and canvas, or iron rust, being freely used to make them steam tight, or constructively solid.

The turning was all of the hand-tool description. The screws were made to suit the ideas of each engineer, and everything else was of the most primitive nature. Even amongst the "thirties," workshop practice seems to have improved very slightly; a change, however, for the better soon afterwards occurred, when Mr. Whitworth left Maudslay and Field's to begin business on his own account in Manchester, where he laid the foundation of the great future of the machining operations, which have now become almost perfect.

In the cylinders before us we have the most exquisite design and workmanship. The castings are beautifully smooth and true, and the metal not only as hard as possible, so that the working surfaces will have extreme durability, but otherwise enabled to resist the corrosive action of the acids contained in the future lubricants. The processes involved in the construction of these cylinders were as follows:

After the working drawings had been very carefully prepared, the patterns were made from them and sent to the foundry to be cast, cleaning and dressing by hand tools and sand blast being the next operation. When thus made ready for machining they were bored, and front and back cover flanges faced up at one setting, the slide valve and other flat surfaces being planed as usual and the steam ports finished. The bolt holes were now marked from standard templets, and then drilled, and screwed, and studded where required, with equal exactness, by means of a special machine. Finally, the joints were finished to perfection in the usual manner.

When completed and tested cylinders are placed in position between the frames, and set centrolineally true with the crank axle, the securing bolt holes are rhymered out, and the bolts tightly driven home as previously described. It will be noted in the Sectional Elevation, that the slide valves are *underneath* instead of between the cylinders as many of them are, thus enabling the latter to be more compactly arranged and better lubricated, and allowing also of longer axle box bearings for the crank axle. In this and other cases, each steam port has an area of one square inch for every 250 cubic inches in the cylinder, the exhaust having similarly a one and a half-inch allowance. These two very simple but empirical rules exemplify many others extensively used in the Works, based, however, on high science considerations.

Another somewhat empirical, but nevertheless eminently practical method of proportioning these and similar details, is to give a thickness to the cylinders beyond what theory would allow, so that the wear and tear of their internal surfaces through high piston speed, insufficient lubrication, etc., and consequent re-boring, may be fully provided for. Hence it comes to pass that the usual thickness of cylinder working barrels of the principal diameters are as follows:— 17″ diameter, $\frac{7}{8}$″ thick; 18″ diameter, 1″; 19″ diameter, $1\frac{1}{8}$″; and 20″ diameter, $1\frac{1}{4}$″.

This simple system, it may be added, permeates the whole domain of mechanical engineering in countless forms, or at least, where wear and tear from any cause, occult or otherwise, have to be allowed for. If, for example, we treat a cylinder as a segment of water pipe 18″ diameter by 1″ thick, the metal of which has a tensile strength of 15,000 pounds, or $6\frac{3}{4}$ tons per square inch, we shall find that it would require 1666 pounds pressure per square inch

to burst it. Inasmuch, however, as cylinder metal is considerably stronger than this, and as the steam is only 160 pounds working pressure, it will be seen that an ample thickness has been given to cover all the contingencies mentioned. The allowance for re-boring, however, as in every other similar case, is made after the mere strengths of the parts have been carefully worked out.

It will be noted that the *Piston Rod Guides* are of the single or "slipper" formation, instead of being double, as is generally the case in locomotives and many other engines. Formerly, they consisted of brass sockets sliding upon guide rods, these, however, though very convenient even in recent times, were imperfect in design. The flat bearing system which followed proved a much better one, as the pressure was more equally distributed over the working surfaces, which had gradually to be made larger as greater pressures and higher speeds came into use. Thus were originated the flat bar guides which are now universal in principle if not in arrangement.

Mr. Holden has applied the slipper system to the Great Eastern locomotives, about 600 of which he has designed and constructed for the Company, more or less in accordance with the drawings we have given of one of his recent engines. It may here be noted that when this plan is adopted in any engine, the distance from the centre of the piston rod to the face of the guide should be as short as possible, to avoid twisting strains, and this, as shown in the longitudinal section, has been well carried out by making the small end of the connecting rod a simple joint, without the cottars, which require much additional space.

The *Connecting Rods* may be either of tough iron, or of mild steel, according to the ideas of the locomotive Superintendent of the Company for which the engines are being

made. It is also the same engineer who regulates the leading features of everything else, to suit the traffic of the line, climate, etc., of the country for which the engines are intended, but at the same time allowing the builders to exercise their own special skill in detailed design and construction.

The importance of having good *Valve Gear* may be gathered from the fact that when well designed and proportioned, as shown in the plates of the Great Eastern engine, the highest excellence in running is the immediate result, whereas any imperfection that may exist will certainly vitiate more or less the performances of the locomotive. This excellence is attained by means of very exact fitting; by the employment of hardened surfaces at every point exposed to wear, and by an arrangement of details which enables the steam to be admitted to and released from the cylinders with the greatest efficiency.

Amongst the numerous improvements that have been made in valve gearing may be mentioned that of Mr. David Joy, by means of which the eccentrics and their attendant rods, quadrants, etc., are dispensed with and simpler details substituted. The essential feature of this gear is that the travel of the valves is produced by two motions derived from the movements of the connecting rod, the position in which their parts are set with regard to each other creating both the forward and backward movements of the engine, and the various degrees of steam expansion.

Amongst the advantages claimed for the above are the nearest approach to a theoretically correct distribution of steam in the cylinders, fewer working parts, with a corresponding reduction in weight and space occupied, and also less cost in maintenance in good working order than with the ordinary link motion.

For *Boiler Feeding* purposes, the old ram pumps worked by eccentrics, etc., were at one time universally employed; Mr. Giffard's invention, however, of the *Injector* in 1858, almost completely displaced the former. Subsequently, various amendments were effected that enchanced the value of the appliance, which may be termed one that enables water to be driven into a boiler by means of its own steam, and without the aid of any of the usual pump machinery. Its advantages include great compactness, easiness of access, perfectly automatic action in starting and stopping, and the facility with which it may be kept in perfect order without dislocating any pipe joint. It may be added that Messrs. Sharp, Stewart & Co. were for many years the sole makers of the injector in Great Britain, in the design and manufacture of which they introduced many improvements.

Having briefly described the various processes by means of which the principal parts of a locomotive have been constructed, let us now proceed with the final operations. This we may remark, is an easy thing to do with all the details lying before us. Now, if the builders wished to make a grand record breaking display of erection, as Mr. Holden did at the Great Eastern Railway Works, they might do so. It may be observed, however, that although such performances indicate the wonderful skill of the erectors, they are not to be commended, as the staff, if powerful enough to win a professional triumph, is too numerous and too expensive to produce commercially economical results.

Mr. Holden's famous engine had cylinders 17½" diameter, by 24" stroke, and had also a tender. When the trial took place, the details were all spread out on the floor ready for use. At the appointed moment the hands raised

the side frames off the ground and fixed them in position over a line of rails. The cylinders and all their attachments, with leading, driving, and trailing wheels, etc., were at once located, every bolt hole being rhymered, every bolt tightly driven home, and every nut screwed hard up. Then came the motion bars, the connecting and coupling rods, valve gear, etc., all of which were swiftly linked to their connections.

After this was done, down went the boiler on its seat only to be fixed up in a twinkling. Next came the mountings, fittings, and all other gear, in rapid succession. Finally, the boiler was lagged, and everything finished off outside, inside, and around it. Whilst these various movements were in progress, the details of the tender were rapidly united, and when everything had been executed "to the entire satisfaction of the engineer," and the engine ready for the photographer, and for running on the line, it was found that the *net* time occupied from first to last had only been 9 hours, 47 minutes!—a truly unparalleled performance, in which, however, the resources of modern mechanical science should have their full share of honour.

The engine and tender whose construction we have had in view all along, will be similarly built and finished off, but not at the same speed, for reasons previously given. When the former has been tried under steam and taken to pieces, the details will be prepared for shipment in a manner suited to their size and nature, after receiving in the *Paint Shop* the required number of coats of colour. The main body of the engine and tender, however, will be rubbed, and scrubbed, and painted, and polished, and touched up until high art perfection is attained.

When the details have been rigidly examined, coated with black varnish at the polished parts, and carefully

inventoried, they are sent to the adjacent *Packing Shop* to be put into strong wooden boxes—sometimes zinc-lined for greater protection—and then forwarded to the ship which has to carry them to India, or elsewhere. If, however, the engine is for a home line, it is run along the rails to its destination, and at once placed on duty. This, we may add, ends our sketchy description of the building of a locomotive in accordance with the drawings given of a Great Eastern engine, and referred to more or less in detail in the foregoing chapters. To make the account more complete, the following particulars are added, which will prove useful when taken in connection with the elaborate plan and sectional elevation which Mr. Holden has kindly allowed us to transfer to our pages.

TABLE OF LEADING DIMENSIONS OF A PASSENGER LOCOMOTIVE FOR GREAT EASTERN RAILWAY.

Cylinders.		
Diameter...	1′	5½″
Stroke	2′	0″
Length of Ports	1′	3″
Width of Steam Ports	0′	1½″
Width of Exhaust Ports	0′	3½″
Centre to Centre of Cylinders	2′	0″
,, ,, Valve Spindles ...	1′	1″
Diameter of Piston Rods	0′	2⅞″
Valve Motion.		
Lap of Valves	0′	0⅞″
Maximum Travel of Valves	0′	3¾″
Mean Lead	0′	0¼″
Travel of Eccentrics	0′	5¾″
Diameter of Eccentric Sheaves	1′	4½″
Length of Crosshead	1′	1¾″
Wheels.		
Leading, Diameter on Tread	4′	0″
Driving and Trailing, Diameter on Tread	5′	8″

Throw of Crank-pins for Coupling Rods	0′ 11″
Diameter " " " "	0′ 3¾″
Length " " " "	0′ 4″
Thickness of Tyres on Tread	0′ 3″
Width " " "	0′ 5⅜″
Axles.	
Leading—	
Diameter of Wheel Seats	0′ 8½″
" Inner Journals	0′ 8¾″
" Outer "	0′ 6″
" at Centre	0′ 6½″
Centres of Inner Bearings	3′ 11″
" Outer "	6′ 10″
Driving—	
Diameter of Wheel Seats	0′ 9″
" Bearings	0′ 7½″
Diameter at Centre	0′ 7″
Centre of Bearings	3′ 10″
Length "	0′ 9″
" Wheel Seat	0′ 8⅛″
" Crank Bearings	0′ 4½″
Diameter " "	0′ 8″
Trailing—	
Diameter of Wheel Seats	0′ 9″
" Bearings	0′ 7½″
" at Centre	0′ 7″
Centres of Bearings	3′ 10″
Length "	0′ 9″
" Wheel Seat	0′ 8⅛″
Frames.	
From Front End to Centre of Leading Wheels	5′ 0″
From Centre of Leading to Centre of Driving Wheels	7′ 9″
From Centre of Driving to Centre of Trailing Wheels	8′ 9″
Distance apart of Main Frames	4′ 1½″
Boiler.	
Height of Centre from Rails	7′ 6″

Length of Barrel	10′	0″
Diameter of Outside	4′	4″
Thickness of Plates	0′	$0\frac{1}{2}''$
„ Smoke Box Tubeplate ...	0′	$0\frac{5}{8}''$
Pitch of Rivets	0′	2″
Diameter of Rivets	0′	$0\frac{13}{16}''$

Firebox Shell.

Length Outside	6′	0″
Breadth Outside at bottom	4′	$0\frac{1}{2}''$
Depth below centre line of Boiler at Front	4′	10″
Depth below Centre line of Boiler at Back	4′	4″
Thickness of Plate (Crown and Sides) ...	0′	$0\frac{1}{2}''$
Centres of Copper Stays	0′	4″
Diameter „ „	0′	1″
Thickness of Throat and Back-plates ...	0′	$0\frac{9}{16}''$

Inside Firebox.

Length at bottom inside	5′	$3\frac{7}{8}''$
Breadth „ „	3′	$4\frac{1}{8}''$
Depth at front end	5′	$7\frac{1}{2}''$
„ „ back	5′	$1\frac{1}{2}''$
Top of Box to inside of Shell	1′	4″
Thickness of Tubeplate at top	0′	1″
„ „ other Plates	0′	$0\frac{1}{2}''$

Tubes (Steel).

Number	252	
Length between Tubeplates	10′	4″
Diameter outside „	0′	$1\frac{5}{8}''$
Thickness ... ... No. 13 I. W. G.		
Diameters of Blast Pipe (Macallan's Variable)	5″ & $5\frac{1}{2}''$	
Height of Chimney from Rail	12′	11″

Heating Surfaces.

Of Tubes	1107·4	sq. feet.
„ Firebox	100·9	„ „
Total	1208·3	„ „
Grate area	18	„

Flue area through Tubes disregarding Ferrules	2·83 sq. feet.
Sectional area of Chimney at smallest part	1·06 " "
Ratio of Grate Surface to Total Heating Surface	1:67·1
Ratio of Flue area through Tubes to Grate area	1:6·36.
Ratio of Sectional area of Chimney to Grate area	1:16·8.

Weight of Engine in Working Order.

	Tons	Cwt.	Qrs.
Leading Wheels	14	2	3
Driving "	13	13	0
Trailing "	12	10	1
Total	40	6	0

Weight of Engine Empty.

	Tons	Cwt.	Qrs.
Leading Wheels	13	1	0
Driving "	12	10	0
Trailing "	11	12	2
Total	37	3	2

The *Machine Constructive Department* at the Atlas Works, is the newest portion of the premises, and is 200 feet long by 110 feet in width. It also independently contains within itself everything necessary for manufacturing purposes, the pattern making, casting, and forging of the details, being executed in the locomotive department. Some idea may be formed of the proceedings in this fine building, when it is known that the machines made in it range in size from those of the light tool class, to colossal slotters, armour plate planers of 115 tons, and great gun and crank shaft lathes of 120 tons.

The elegance of design and beauty of finish which form the distinguishing features of high class modern machinery, are of more practical value than many would suppose, even

in these days of rigid economy. To give my own experience in these matters when sent to the Works on trial for a month, I may here observe that I was so fascinated by the Whitworth machinery around me that I at once became an enthusiastic engineer. Hence, from these and subsequent experiences, and general knowledge of workmen's idiosyncrasies, I can feelingly testify that so long as the love of the beautiful exists in peoples' minds so long will they become influenced in their occupations by something better than mere duty. An ugly engine or machine roughly finished and consequently difficult to clean, will be kept in a dirty state by its attendant; give him, however, high class mechanisms to manipulate and he will take a pride in his work, and do more of it with greater pleasure.

To the initiated this touch of nature is well known, and taken advantage of in very many ways on land and sea, and therefore, there is no excuse for users of machinery supposing that anything will do for externals so long as they are cheap enough. This system is so inherently bad, that everything which affects the taste of the public, as well as that of the mere workman, is now run more extensively than ever upon the lines of beauty, because they are found to be profitable.

From the foregoing remarks upon high class machinery, and its uses in locomotive construction alone, it will be apparent that it is absolutely necessary for rapidly and profitably conducting every workshop operation, and perhaps one of the best examples of its power, even in past days, it is to be found in the history of the North London Railway.

This line was opened in 1850, but its locomotive works were not built until five years afterwards. In the meantime, a gigantic traffic had sprung up, and when the

making of their own engines was added to that of repairing, the Company was nearly overwhelmed with work which had to be executed at all hazards. So great was the strain upon the establishment at one time, that the Directors hardly knew how to deal with it. The men were working on night and day shifts doing repairs, but in spite of this, no engine could be spared long enough to enable its defects to be properly rectified at one lying up. The line and workshops were therefore taxed far beyond their capacities, and to tide them over the difficulty, special, and in some cases, very simple machinery had to be devised. Besides this, there were little things known as "appliances," which helped very materially in rendering assistance, and to crown all, a most admirable system of management was planned and carefully worked out in every little detail. These united and well directed efforts eventually produced the happiest results.

Amongst the most important recent changes in workshop practice may be mentioned the system of cutting the teeth of wheels out of the solid, instead of casting them, as was formerly the case. The latter method has now become almost abolished in high class machines, since it is necessarily deficient in accuracy, and also in those smooth working properties *cut* teeth so eminently possess which the milling machine has now rendered obtainable at small cost.

For the above purpose a *Universal Gear-cutting Machine* is now most sucessfully employed, in which, after a blank wheel has been set in position, and the machine adjusted and started, suitable gearing automatically feeds the cutter through the rim, rapidly withdraws it again, moves the blank the correct distance for the next tooth, and so on, until the striking of a gong announces to the attendant

that the work is finished. In various sizes, these machines are made to cut the teeth of spur, bevel, and worm wheels, up to 7 feet diameter, and from $\frac{1}{8}''$ to $3''$ in pitch, the number of teeth sometimes exceeding 200.

It may be well to add that no one perhaps has a more extensive knowledge of the various causes of break-downs in machinery than Mr. Michael Longridge, the chief engineer to the Engine, Boiler, and Employers' Insurance Company Limited, whose investigations have been the means of detecting many weak points in details and arrangements previously undiscovered, one of which has an important bearing upon present practice in wheel gearing.

For a long series of years the teeth of spur wheels had a length of three fourths of the pitch, now, however, Mr. Longridge recommends very short teeth, as these are stronger, and more durable through their decreased clearance and back lash. In proof of this it may be mentioned that for some time past Messrs. Hetherington, and others, have employed a tooth of one half to five-eighths of the pitch in length, as greater smoothness in working and less liability to fracture are thus ensured.

To enable weights of any kind to be transported with facility from one point to another of a workshop, it is essential that suitable lifting appliances should be provided. This has been done most efficiently at the Atlas Works by means of cranes by Messrs. Craven, some of which are *over-head travellers* from 10 to 30 tons capacity, the others being special 4 to 5 ton *jib cranes* of 12 to 16 feet radius. The former are driven by high speed cotton ropes, which, with other gearing, enable weights to be noiselessly lifted at varying velocities, and rapidly deposited at any required spot, the attendant being placed in a cage attached to the

underside of the crane, so as to have a clear view of the work below.

The jib cranes are also rope driven, and are used in the machine shops, up and down which they are made to travel. Each of them rests upon a two wheeled carriage which runs upon a single rail bedded in the floor, the top part being guided by two light rolled girders carried by the roof principals. This arrangement allows the jibs to swing completely round, thus serving the machines over the whole area of the floor in the most handy manner as the cranes are moved along from point to point.

The great value of the above "Walking" order of lifting appliances may be gathered from the fact, that in the crowded machine shops of locomotive works it is not expedient to use overhead cranes, as they cannot serve the machines individually with the necessary completeness. It will therefore be seen, that the amended cranes, under certain conditions of application, are unapproachable for usefulness.

CHAPTER XI.

NARROW GAUGE AND PORTABLE RAILWAYS.

Prominent objects on a Main Line—How Railway Travelling became the "Safest of all Occupations"—Land Transportation of the "Twenties"—Early Tram Lines and their Development—New Departure in 1830—Early Permanent Way Breakdowns—Present Standard System—Stamped Steel Sleepers—Extraordinary Corrosion of Steel Rails—Flanged Rails—Portable Railways and their Uses—Popular Gauges—Weight of Rails for various Services—Points and Crossings—Turntables—Considerations affecting Design of Portable Railways—Applications of the System—Its value in new Countries—Comparative Cost of Working—Freight Peculiarities.

HAVING described the leading features of locomotives, as well as one of the establishments in which they are manufactured, we may direct attention to the roads on which they are to run, and also to the *Engineering of Railways* and their connections from various points of view, with the object of showing how railways and their accessories are constructed by the aid of the latest appliances, and also the peculiar features of a system which is now practically perfect.

To those who care to walk over even a small portion of one of our great lines, the gradually unfolding scene that presents itself is of the most interesting nature. Quite apart from the engines and other rolling stock so continuously visible, there is a great deal to note on the road itself that may at least adorn a tale, and help to make railway travelling attractive to ordinary students of science. As one, for instance, gets clear of a station, the rails,

sleepers, points, crossings, signalling apparatus, etc, rise to view in rapid succession, all of which have histories of their own, and stories to tell of awful disasters in the past through failures at vital points, which have long since been rectified. Our first object, therefore, is to show how modern improvements have been so utilised as eventually to have enabled upwards of 800,000,000 passengers, exclusive of season ticket-holders, to be carried during one year on all the railways of the United Kingdom, with the loss of only five lives by accidents to trains, which in many cases were unavoidable through circumstances over which no one had any control.

Formerly, the traffic was extremely limited, and disasters more or less fatal were of frequent occurrence, distinct causes being assigned for each of the above. In the first place the trains of the "fifties" and "sixties" had third class carriages that were merely cold, cheerless, naked, and uncomfortable boxes on wheels, the high fares and slow system of travelling additionally delaying the enormous extension of traffic which the greatly improved facilities of the present have so successfully created. Secondly, a succession of terrible accidents, due to faulty lines and rolling stock, imperfect signalling apparatus, an inefficient system throughout, and an improperly educated staff, showed where improvements were necessary, the result being that the railway travelling of to-day—as recently publicly stated by the Chairman of Directors of the London and North-Western Company—is the "*safest of all occupations.*"

Comparisons of an extreme nature are often very useful, and help to throw light upon things obscure, consequently the best way of realising the immense benefits conferred upon the world by the introduction of railways is to view

the state of our travelling resources previous to the "thirties" of the present century.

At that period, the most rapid transportation from place to place was effected by means of stage coaches, whose passengers were exposed to great privations and even serious danger whilst on a long journey during winter. When railways, however, became successfully established, the new order of things gradually abolished all that had previously existed on land, and paved the way for ocean steam navigation as we now have it.

It is commonly believed that Stephenson was the originator of the Railway System, but it is not so generally known that the initial movements in this direction were made about the middle of the seventeenth century, by means of the tramways which were then laid in the mining districts of England to enable coal to be easily carried to the sea. In those days, heavy traffic had a destructive effect, not only on the vehicles themselves, but upon the wretched roads they traversed, to the great inconvenience of many. To obviate this difficulty, timbers were placed at the bottom of the ruts, and this suggested the idea of laying planks on the surface of the ground, which was considered a great improvement. In 1676, the first *Tramways* consisted of flat timbers laid parallel, and with transverse pieces fixed between them, the carriages that ran upon the former having wheels made to suit, thus enabling a horse to do much more work than formerly.

The next movement was to place false wooden rails on the top of the others, which could be easily removed when worn, and to make this system still more effectual, flat bars of iron, 2" by ½", were used instead of wood, and secured to the tram timbers by means of spikes. These, however, would not act well under severe usage, as the spikes

became loose, and the rails so dislocated as to seriously impede the growing traffic, which had now risen from the original horse load of 17 hundredweight on a common road, to one of 42 hundredweight on the iron-faced tram road.

In the year 1767 the Coalbrookdale Iron Company were the first to employ cast iron plate rails of 5′ 0″ in length, 4″ in width, and 1¼″ in thickness, each piece being fastened by spikes to the longitudinal oak sleepers beneath them. Then came ribbed and flanged plates of greater strength, which formed a guide for the wheels, and abolished the old timber bearers, stone supports at the end of each plate being used instead, the "*plate layers*" doing all that was necessary in this respect. Other improvements were introduced by degrees, amongst which were the first malleable iron rails of Mr. Birkinshaw, in 1820. These, of the fish-belly T section, 28 lbs. per yard, were used on the Stockton and Darlington Railway of 1825, and subsequently of 35 lbs. per yard, and 15 feet lengths, on the Liverpool and Manchester line of 1830, thus bringing about an entirely new departure.

In both of these cases the rails were fastened to chairs by iron keys, while the latter were fixed to stone blocks 2′ 0″ square, rigidly bedded on a hard broken stone foundation. The enormous expansion of traffic that followed the opening of the L. and M. Railway, and the increased speed and weight of the engines, rapidly destroyed the line, which had to be replaced by a structure of greater strength, and also a certain amount of elasticity, with the object of relieving the severe shocks and vibration to which it was constantly exposed.

A further series of break-downs of the "*permanent*" way indicated the necessity of having better arrangements, the whole subject, therefore, received full consideration by the

most experienced engineers of the day, including Mr. Brunel, who introduced longitudinal sleepers on his Great Western Railway. These were of timber 14″ by 7″, on the top of which were laid flat bottomed rails of 44 to 62 pounds per yard, that seemed, for a time at least, to suit their intended purpose.

Numerous other changes were made in the rails and their connections as time rolled on, until, at last, a very simple and satisfactory arrangement was adopted. The standard system now practically universal in this country, and in modified forms throughout the world, is to bed transversely on a well made road sleepers 10″ by 5″, and about 3′ 0″ centre to centre, except at the joints, where they are about 2′ 3″ apart. On these sleepers the chairs are spiked, and to the same chairs steel rails of the most approved section are secured by means of wooden keys, which are rapidly shaped to gauge in enormous numbers by a special machine.

The rails are left nearly $\frac{1}{4}$″ open at the ends, which are securely bolted to each other by fish plates on each side that do not obstruct in any way the longitudinal expansion and contraction of the rails by heat and cold. To enable the sleepers to last as long as possible they are placed in tanks and creosoted as described on page 59. In foreign countries, however, steel sleepers are used for the same purpose, and also to repel the destructive attacks of worms, whose ravages in some places have to be guarded against.

On this point it may be said that a few years ago a series of accidents occurred at Hagen, in Germany, which completely puzzled the authorities. A rigid investigation, extending over several months, was therefore instituted by the Government, which ended in the discovery that a

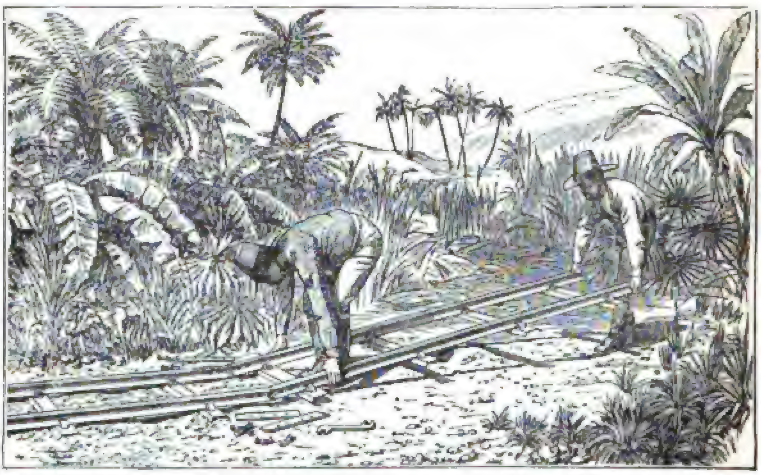
peculiar kind of worm had honeycombed the steel rails to destruction by means of very frequent injections from its head of a powerfully corrosive fluid. This so disintegrated the metal as to enable it to be actually used as food.

The metal sleepers referred to are variously made, one of the most popular kinds being of the flanged trough section shown in some of the following views, which combines great strength with lightness, and may be rolled in long pieces and sawn to the required lengths, whilst others are formed out of mild steel plates stamped to shape by hydraulic pressure. These sleepers are most extensively employed on narrow gauge and portable railways, as no skilled labour is required in fixing, whilst accuracy of gauge is automatically insured by means of clips pressed out of the solid plate, the rails being held in position by steel wedges. They also last much longer than timber.

The rails incidentally shown in some of the following illustrations, are of the very popular Vignoles or flanged section, and are made up to at least 70 pounds per yard, those from 10 to 25 pounds being specially adapted for *Portable Railways*, whose engines range from 4 to 10 tons each. These railways have proved invaluable at home and abroad for contractors' operations of all kinds, also for work in various plantations, brickyards, gas works, forest clearings, sugar estates, etc., where mules, horses, or bullocks, can be easily obtained as well as engine power. Not only are they highly appreciated on account of the immense saving of labour they effect, but owing also to the ease with which a line may be moved from one spot and re-laid in another by unskilled hands, four men being able to take up nearly 250 yards and re-lay it 50 yards off in about half-an-hour, as shown in the view on next page of the plan usually adopted.

Each length is built up complete in itself when ready for laying in position, the rails being fixed to the sleepers at the exact distance apart, and the ends fish plated with bolts as shown, or automatically jointed in dovetail fashion by means of a special plate riveted on each end.

The *Gauges* employed in *Portable Railways* vary from 16, 18, 20, and 24 to 30 inches, each having advantages suited to the purpose for which the line and the tractive power are employed. The 16″ and 18″ gauges, with rails



PORTABLE RAIL LAYING.

10 to 12 pounds per yards, are preferable where *manual* power is used and the loads light and compact; the 20″ and 24″ gauges with 14 to 16 pound rails, being best suited for mule, horse, or bullock power; whilst the 24″ to 30″ gauges having 18 to fully 20 pound rails, do well for locomotive traction. These rails are usually cut to 15 feet lengths, but their weight, as approximately indicated above, should additionally be made to suit the loads that are to run over

them, and also the nature of the ground on which they are to lie, according as it is soft or loose, or more or less uneven.

On portable railways, a somewhat peculiar system of Points and Crossings is employed, which may be clearly understood from the annexed views of an *Inclined Plane and Curved Off Railer*, by Messrs. Dick, Kerr & Co., for

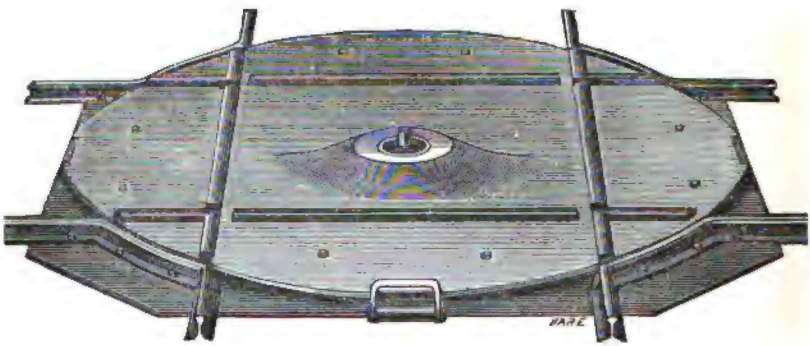
INCLINED PLANE AND CURVED OFF RAILER.

changing the direction of a train, and also a *Double Inclined Plane* for mere crossing purposes. As will be noted, the curved and also the straight crossings pass *over* the rails, instead of being flush with them, as in other lines; they

DOUBLE INCLINED PLANE

also automatically clip the main rails, thus keeping themselves in position as long as required. By this plan each piece can be easily removed when not wanted, and the fore and aft traffic maintained as before.

When rectangular changes of direction are frequently needed, a *Portable Turntable* is used, as shown in the adjacent illustration. This apparatus is designed to suit the various gauges of rails, the top being of wrought iron plate, and made to revolve upon a steel centre pin fixed to the flat wrought iron base plate. A hinged catch, jointed to the latter, securely locks the table in any one of its four positions, the whole turntable being complete in itself and capable of instant removal, as it simply rests on the surface of the ground.



PORTABLE TURNTABLE.

The success of a *Portable Railway* depends very much upon the following considerations:—

1. The greatest strength being combined with the least weight.

2. That the various straight and curved sections, crossings, turntables, etc., are all interchangeable, and easily carried by one or two men.

3. That the fastenings of the rails to the sleepers shall not produce any local weakness, and cannot be broken by carts or wagons crossing the line.

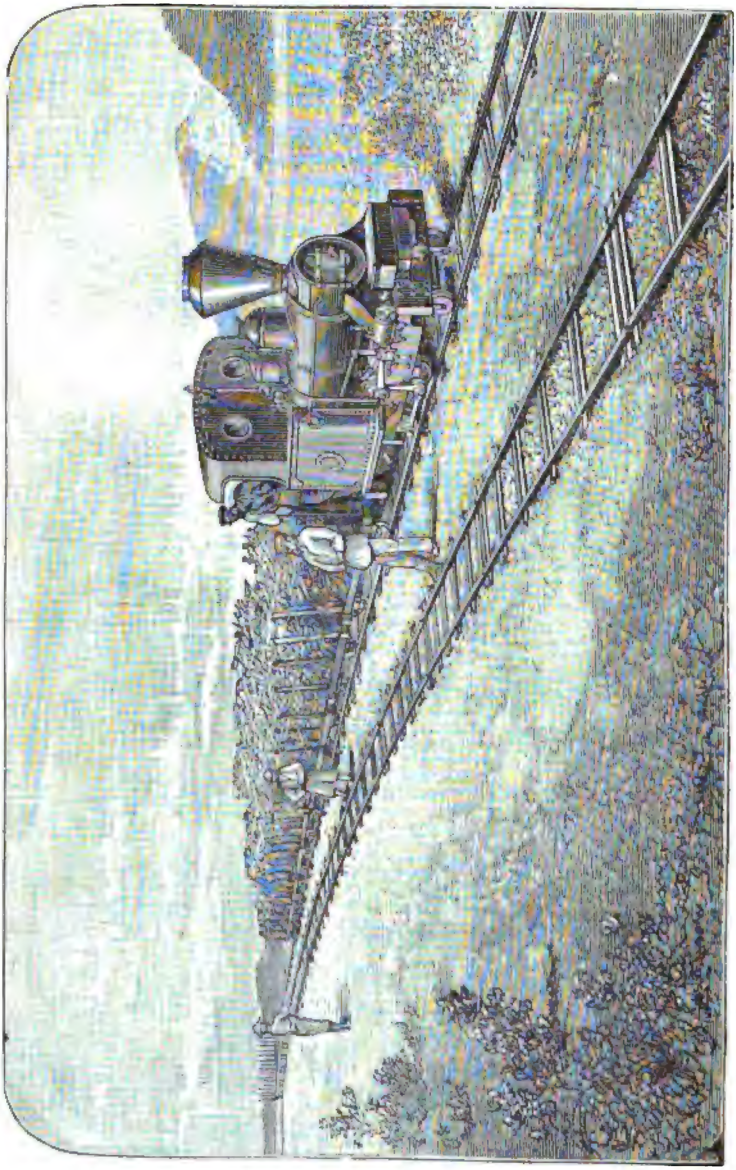
4. That the selected gauge will allow numbers 1 and 2 to be adhered to, and be the most suitable for the traffic.

5. That the construction of the railway shall be so simple that no skilled labour is required to lay it down, and that the line as a whole will be able to withstand rough usage in various ways.

The Plate on next page illustrates in a general manner the application of the system, on the plan of Messrs. John Fowler & Co., to a pioneer or feeding railway of 30″ gauge. In this case, as in all others, the permanent way is laid on the natural surface of the ground, corrugated sleepers being used, which have become very popular.

These miniature lines may seem to have very little to do with the great railway world, but, insignificant as they appear, there is quite enough in them from various points of view to interest many. What we here note, however, is only in connection with lines suited to the requirements of factories, mines, plantations, or a *new and undeveloped* country where those of the ordinary type would be workable only at a loss.

In cases where facility of transport is of importance, and the carrying of considerable goods traffic for short distances a necessity, a Portable railway will prove most useful and economical. At first sight the insufficient nature of the line itself may be somewhat strikingly visible, but the difficulty is got over easily enough by distributing the loads to be carried on a suitable number of small wagons, and thus locating the weights upon the rails at as many points as possible. When this is done, the amount of work which can be accomplished by means of animal, or manual power even, is astonishing. For instance, a man with an equilibrium tipping wagon, such as that illustrated further on, can take a cubic yard of earth on a portable



PORTABLE RAILWAY, SIDE TANK LOCOMOTIVE, AND TRUCKS ATTACHED.

line a distance of 220 yards, discharge the same and return in five minutes, whereas it would be good work for the same man to perform the same operation in one hour with a barrow.

By taking a week's labour under both systems, the following results may be deduced. If ten wagons per day of ten hours are employed, 6,000 cubic yards can be carried at a cost of £12 10s. on a Portable railway, while the same tonnage by the manual method would cost £150. The outlay upon the line and wagons would be £110, but if the work had to be executed in the same time by means of barrows, the cost of 125 of these alone would be £90, and if, as frequently happens, wheeling planks are required, the total expenditure on both of these systems would be practically the same.

The foregoing example, taken from the practice of Messrs. Dick, Kerr & Co., is not by any means an extreme case, since in plantation work not only can similar economy be found, but in clearing such crops as sugar, it is most important to harvest the crop while the cane retains its highest price. On many estates, with the use of a portable line, 200 tons of cane per day may be easily brought in, thus reducing the crushing season by some weeks, to the great advantage of the planters.

Portable railways are very usefully employed in other ways besides the above, admirable illustrations of which are to be found in the 22" gauge line at the vast brewery of Messrs. Guinness & Co., of Dublin, and the 18" gauge lines at Woolwich Arsenal, the Crewe Railway Works, and many others. For military purposes too, these little lines are much used in the construction of fortifications, or in the transport of provisions and ammunition, Germany having adopted them very extensively. In addition to this

they are very popular on canal, harbour, railway, and other great public works, which will clearly indicate the diversified application of a system that, small as it is in detail, is nevertheless of great value in places where it can be suitably used.

The term "Portable" when applied to railways, is intended to mean those only whose complete sections of 15 feet each in length are capable of being carried by one or two men, those containing one sleeper for every yard of line weighing as follows:—

Rails	10	lbs. per yd.,	16″	gauge,	130	lbs.	per section.
"	14	" "	16″	"	180	"	"
"	18	" "	24″	"	285	"	"

The mild steel used for the rails should stand a tensile breaking strain of 39 tons per square inch, 17 per cent. elongation, and 39 per cent. contraction at the point of fracture. Whilst the above proportions for sleepers should be respectively 32 tons tension, 20 per cent. elongation, and 45 per cent. contraction. They should also be able to stand hammering in a flat form and bending double without fracture.

The next point of vital importance is the rail fastenings, upon which not only the accuracy of the gauge but the safety of the line depends. After much experimenting Mr. Kerr ascertained that those exhibited in the engravings were the simplest and most efficient, and at the same time the least expensive in manufacture. The fastenings referred to consist of a dog-head rivet on one side of the rail, and a loose clip and bolt on the other side, both of which fit closely over the angled flange and hold it firmly to gauge.

The absolute accuracy of the operation is ensured by punching simultaneously the four holes required in a special

machine after the sleepers have been sawn to dead lengths. By these means, the whole line can easily be packed for transport in pieces, no skilled labour being required for laying in position on arrival at site.

The talented Monsieur Decauville, who has played an important part in the introduction of Portable railways, strongly advocates the system of rivetting the rails to the sleepers, which is in itself the very essence of simplicity, and Messrs. John Fowler & Co, employ an admirable system of their own of a detachable nature, which is highly appreciated. It may be remarked, however, that no riveted system is economical from a *transport* point of view, owing to the difference in cost between goods carried as dead weight and those paid for by measurement. For example, one mile of 18″ gauge railway, with 10 pound per yard rails on Mr. Kerr's plan, will have a shipping weight of 22 tons, but if riveted up would be charged for as 46 tons. Thus illustrating in one out of a thousand instances the manner in which the greatest skill in engineering design is often hampered by commercial considerations.

In this chapter we have only referred to portable railways from a general point of view, quite apart from their very useful and economical application to workshop management, where there is often an immense field. The introduction of overhead travelling cranes was a great improvement upon the old jib crane system, but these, in modern practice, are not sufficient, as they are limited in their scope by the length of the shop in which they are placed, and by the distance between the girders on which they run. They cannot travel from shop to shop, neither can they traverse curves, and besides these unavoidable defects, the constant weight of their own ponderous bodies has to be moved whether the load to be carried amounts to one

or to 50 tons, so that even here a large quantity of power is lost. In the ordinary wagons of the standard gauge on the other hand, the carrying capacity varies from 1½ times to twice the deadweight, but on a 24″ gauge line a well designed truck will carry about four times its own weight in the most easily applicable and convenient manner.

The great usefulness of the 18″ gauge track at the Crewe Works may be gathered from the fact that it most efficiently acts as an auxiliary to the five miles of standard gauge line spread over the whole area of that colossal establishment, as well as indispensably in other places of lesser degree. The engines used at the former are of the following dimensions:—

Cylinders	5¼″ diam. by 6″ stroke.
Wheels	16½″ diam.
Wheel base	3′ 0″
Total length of engine	8′ 8″
Height from rail level to centre of boiler	2′ 11¾″
Diameter of boiler (outside)	2′ 3″
Heating surface	57·91 sq. ft.
Grate area	1·50 sq. ft.
Boiler pressure	160 lbs. per sq. in.

The above are employed not only to draw narrow gauge trucks, but also main line wagons, and even engines and tenders, from one shed to another. The same remarks are applicable to the new Lancashire and Yorkshire Railway Works at Horwich, where the miniature engines are nearly the same size as those at Crewe. A strange peculiarity, however, of these engines, is that their hauling power is greater in proportion to their weight than in those of the main line, which has been clearly shown in the 1′ 11½″ gauge Festiniog and other similar locomotives.

CHAPTER XII.

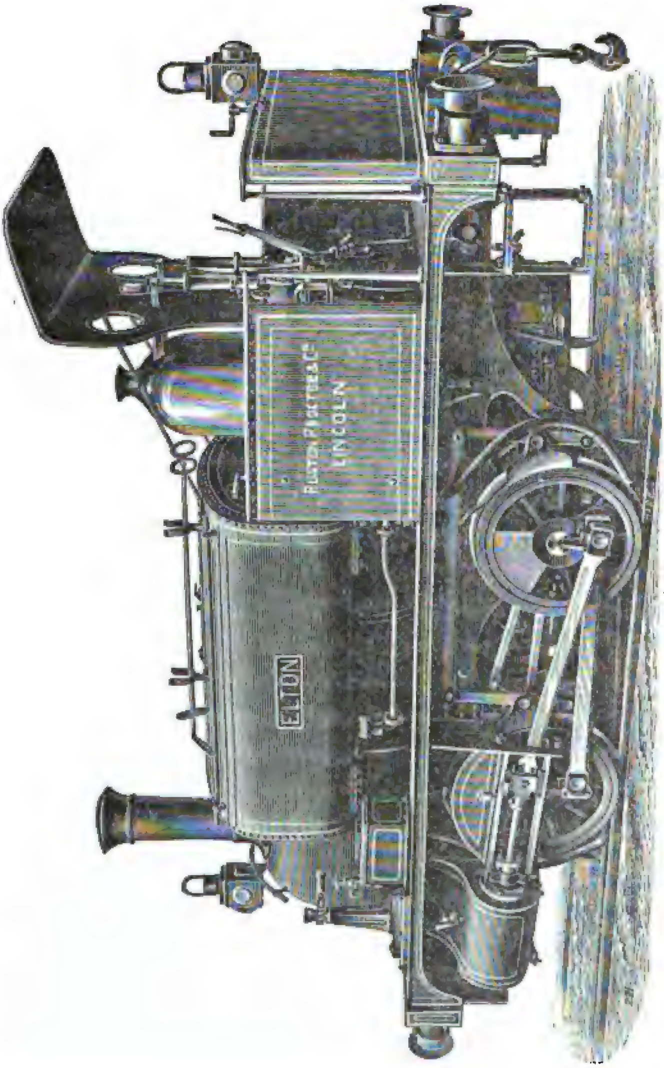
PORTABLE LINE ROLLING STOCK—HORSE, CABLE AND ELECTRIC TRAMWAYS.

Portable Railway Locomotives—Tipping and other Wagons—Timber carrying Wagons—Passenger Carriages—Early Tramways—First Tramway in England—Experimental trial in Liverpool—Special Peculiarities of a Tram Line—Primary Considerations—Construction of the Line—Cable Tramways and their Advantages—Main Feature of the System—Details and their Requirements—Electrical Traction—Various Systems and their Peculiarities—Cable and Electric Tramways compared — New Method of greatly decreasing Frictional Resistance—Notes upon the Finance portion of Tramway Working.

HAVING briefly gone over the line itself, we may now direct attention to its accessories and rolling stock, which more or less indicate the design and construction of similar plant for semi-portable and other light railways.

First in order, then, let us take the *Saddle Tank Locomotive*, shown in the Plate on next page, which clearly exemplifies a type of four wheeled engine of various sizes that does not require a *tender*, and whose short wheel base enables it to pass round sharp curves with safety. Various modifications of these are made to suit different gauges, and in districts where timber is abundant, the fire boxes are made large enough to enable steam to be raised with wood, or dried megass fuel, which, in foreign parts, are often used instead of coal.

In the practice of Messrs. Dick, Kerr & Co., these engines are generally made in accordance with the accompanying table of leading dimensions.



SADDLE TANK LOCOMOTIVE.

TABLE OF PORTABLE RAILWAY LOCOMOTIVES.

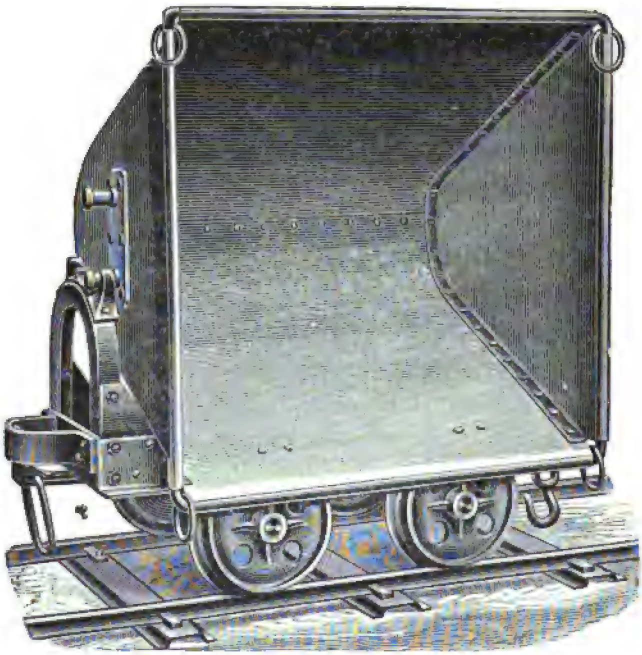
Diam. of Cyl'der.	Length of Stroke.	Diam. of Wheels.	Wheel Base.	Water Cap-acity.	Fuel Space.	Will Haul on Level.	Will Haul on 1 in 50.	Approx. Weight W'king Order.	Suitable Weight of Rails.
ins.	ins.	ins.	ft. ins.	galls.	cub. ft.	tons.	tons.	tons.	per yd.
4	8	16	2 9	70	7	38	8	4½	16 lbs.
5	10	20	3 0	80	7	63	15	5	18 "
6	12	24	4 0	100	10	93	22	7	20 "
7	14	27	4 6	150	12	133	32	8½	25 "

The engraving opposite illustrates one of the standard gauge locomotives built by Messrs. Ruston, Proctor & Co., which were so effectively employed upon the Manchester Ship Canal works. The cylinders are 10″ diameter, and stroke 16″, the cast-iron steel-tyred wheels being 2′ 9″ diameter, and base 5′ 0″

In works such as those for mining, chemical, and gas producing purposes, harbour, dock, and railway excavations, or for loading and unloading cargoes of raw material, labour is immensely facilitated by having wagons that are specially adapted to their requirements. This is accomplished in various ways, one of which is by having a good supply of side or end tipping wagons, both of which are shown on the next two pages.

The *Equilibrium Side Tipping Wagon* is of steel throughout, the under frame being securely stayed and riveted. Economy of space in shipment has here been satisfactorily obtained, as all the parts when taken to pieces can be packed inside the body of the wagon. The sheets out of which the tipping box is made are strengthened and neatly finished at the top edge by being bent over

a round bar, whilst the box itself is carried on four trunnions supported on angle iron standards, and is thus enabled to tilt on either side, or, by means of a simple arrangement, all round if required. The capacity of the boxes ranges from 10 to 27 cubic feet, the rail gauge from 16" to 30", and the diameter of the wheels from 10" to 14",

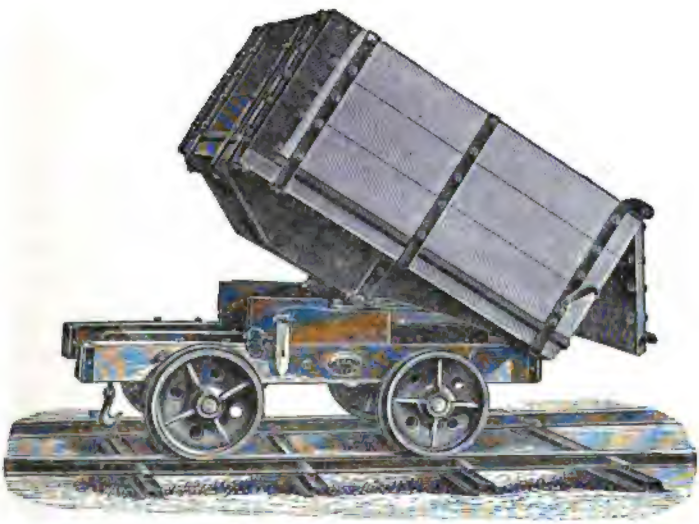


EQUILIBRIUM SIDE TIPPING WAGGON.

the wagons as a whole being of various designs to suit different kinds of work.

The *End Tipping Wagon*, shown opposite, has an under frame of oak, and a tipping box of red deal well bound at the corners. Everything else is of steel, and the whole structure is not only very simple but strong enough to withstand severe treatment.

For forest clearing and military purposes, etc., a totally different arrangement is employed for gauges from 16″ to about 40″, two plain flat-topped wagons, united to each other by chains of adjustable length, coming in very handy for the transport of trees and other long and bulky material. These are of the utmost importance in all wooded countries, where immense quantities of timber have to be removed. This plan is well adapted not only



END TIPPING WAGON.

for distributing heavy weights, but also for passing them with ease round curves which otherwise could not be traversed in safety, the logs being placed on swivelling supports which can be removed when not wanted, and the coupling chains either shortened to suit a different load or disconnected altogether.

There are many other portable railway cars or wagons that might here be described, if space permitted; we must

not, however, omit to mention the *Passenger Carriages*, which are of a very simple nature, and which in their own way are very useful and diversified. These are of the open and also of the closed description, the former having their seats placed either transversely or longitudinally over lines ranging from 18″ to 36″ gauge. The top framework simply consists of vertical stanchions diagonally or otherwise braced, and is capable of easy disconnection, whilst the roof is of corrugated metal. The other carriages are closed in and have a conductor's platform at each end, with the brake gear conveniently placed, the wheel base being made as short as possible.

TRAMWAYS.

It will be seen that the scope of Portable Railways is a very wide one, and their application greatly varied. There is, however, another railway which is quite distinct from the above, and although workable by cable and by electricity, etc., horse traction is still occasionally employed for convenience. The *Street Tramway* to which we refer has been the result of the persistent and laborious efforts of many talented inventors and engineers, whose failures, unhappily for themselves, only paved the way for the successes of others, and, insignificant as the two lines of steel that run along our streets may appear, owing to the absence of visible foundations, they are nevertheless very costly.

The modern tramway was originated in the United States, where it proved most useful owing to the wretched condition of the streets of the towns and cities, the first of these roads having been the New York and Haarlem line, which was opened in 1832. This was of the 4′ 8½″ gauge, but after all that could be done to make it a success it was ultimately suspended. Through the agency of M. Laubât,

a French engineer, an amended line was put down in 1852, which proved so beneficial that tram roads became an indispensable feature of many of the large communities. So much so indeed that Mr. G. F. Train, of American celebrity, came to England and laid the first of the European tramways at Birkenhead, opening it amidst popular demonstrations, on August 30, 1860.

In 1865, an experimental trial was made in Liverpool, with the object of fully ascertaining the merits of the invention, and soon afterwards, the first line of the now immensely extended system was laid in that city, the foundations consisting of longitudinal timber sleepers to which the rails were spiked. Cross ties held these in position, and, when everything was fixed, the intervening spaces were filled in with concrete to the required level. On the top of this a layer of sand was spread, on which sand the paving stones were bedded, and then grouted and rammed, until they had a solid bearing underneath and a fair surface at the top. Strange as it may seem, the early mistake of the Staffordshire engineers in spiking iron plates to longitudinal *timber* bearers was reproduced at the outset of the tramway career, but with this difference, that instead of mere flat or flanged plates, shallow rails were used whose sections were extraordinarily diversified.

It may here be said that a tram road differs materially from a railway in its foundations, since the *elasticity* of the latter is an advantage, the sleepers being laid in ballast well drained, and so accessible for examination that defects can be easily discovered at any time. On the other hand, tramways are best laid on a *rigid* bed, as the whole of the foundations are buried out of sight, and incapable of inspection without taking up, at great expense, portions of a thoroughly consolidated street. Hence the necessity of

employing something more durable than timber, which needs frequent and costly renewals, the spike fastenings of the rails also working loose and becoming difficult to secure.

The main apparent difference between a tram line and all others is that its lies flush with the surface of a road or street, and thus offers no obstruction to ordinary vehicles, whilst, at the same time, the rails are not only exposed to the wear and tear of their own traffic, but, additionally, to that of heavy wagons, etc., of a most irregular character, that are constantly running over them, the tendency of which, in early years, was to dislocate the rails and their fixings at many points. Under the present system of permanent way, however, there is little to be desired, as wooden sleepers have been superseded by deep steel rails, whose bottom flanges rest continuously upon concrete as hard as rock, thus practically abolishing the necessity for repairs of any kind.

When a line has to be designed, the first consideration is whether it shall be a single or a double one, bearing in mind, at the same time, that although, in most cases, the former would cost much less than the latter, in some instances the advantage has been more imaginary than real. The Tramways Act specifies that every line shall be laid in the middle of the road, and that the rails shall not, for a distance exceeding 30 feet, be within 9′ 6″ of the face of the kerb stone. When these conditions cannot be complied with owing to the road being too narrow, such confined places must be described and marked upon the Parliamentary plans for special discussion.

The *Width of Gauge* is another vital point, as may be gathered from two leading facts, one being that by employing say a 3′ 6″ instead of a 4′ 8½″ gauge, the first cost of the work may be reduced. In addition to this,

a narrow gauge tramway admits of curves of smaller radius, which often means a considerable saving in the purchase of land, or the displacement of footpaths, besides what is effected in labour and material.

On the other hand, it costs more to keep in working order than one of 4′ 8½″, all conditions being similar, since in the former case the wheels of street vehicles will run partly on one rail and partly on the paved margin of the other, thus creating objectionable ruts in the street. With the standard gauge, however, this difficulty is avoided, since, true to the traditions of the past, the wheels of carriages and wagons will generally pass over both rails at the same time, as their drivers wish them to do for the sake of easier running. Another objection to the narrow gauge is that the cars have too little stability when heavily loaded with passengers on the top, and this danger becomes more accentuated when curves of small radius are passed over at great speed. With all these facts in view, the practical utility of the standard gauge under certain conditions becomes fully apparent; in hot countries, however, where no top loads are carried, narrow gauge lines are employed with excellent results.

Next in order to the above considerations come those of *Construction*, and upon these depends the economical maintenance of the proposed line. If this is intended to be laid through the principal streets of a great city, the permanent way should be very substantial, so that it may be able to withstand the shocks of the heaviest and most continuous traffic without being loosened at any point, or subjected to repairs that may be avoided at the outset. To enable this to be accomplished, very heavy deep webbed rails are necessary, say from 80 to 100 pounds per yard, the fish plating being as rigid as possible.

The rails rest upon a bed of concrete, which forms an unyielding base, and their webs are bound together by means of tie bars about 9′ 0″ apart, the whole being finished off with set stones of granite, etc. The interstices between these stones are then filled in either with pitch grouting, or with cement grouting, the former being best adapted for a town, as it stands the traffic better, can be repaired more quickly and thoroughly, and is ready for traffic in an hour after the operation is performed. Cement grouting, on the other hand, may be used for outlying districts, but should be allowed to harden before vehicles can pass over it, and thus become capable of persistently standing the most severe usage.

For country, or colonial lines, where cheapness in construction is generally the leading feature, many of them are of narrow gauge, made up to the rail level with macadam. By this means, the first cost in England is reduced about 40 per cent., and so successfully has the system been adopted, that tramways otherwise impracticable on account of their expense have become possible.

The rails most suitably employed are similar to those already mentioned, but of lesser weight. They may either be laid on steel cross sleepers, 3′ 0″ pitch, of trough section as previously illustrated for portable lines, or on timber cross sleepers, 9″ by 4″. The former should be beaten down on a layer of concrete about 4″ thick under each sleeper, but with the latter, good solid macadam is sufficient for the purpose.

Cable Tramways.

The first design for a *Cable Tramway* in England was originated by an American engineer, and although he was closely associated in this matter with one in England, it

was a good thing for both that their plans were not carried out, on account of inherent defects. Various improvements were made in the system, and these resulted in an arrangement which was much more economical, and more suitable for street traffic.

A Cable Tramway may be described as one that enables street cars to make use of a wire rope concealed in a tube underneath the surface of the road, and kept constantly moving in one direction at a given maximum speed from a power station. By means of car gripping gear working through a slot about $\frac{5}{8}''$ wide in the road, a driver can enable his car to be propelled at the full speed of the cable, or at any reduced speed that may be desired. Hence, it will noted that the economy of a line must increase with the traffic, as the power expended in creating the means of propulsion at various points along the route is a constant charge. This feature in the arrangement at first sight appears to be a weak point, but in practice it is not so except in unsuitable places.

One of the leading features of the system is its power to meet increased traffic at a minimum expenditure. Besides this, hilly districts are practically made equal to level roads, since the descending cars attached to the cable assist the engines in overcoming the extra work thus thrown upon them by the ascending vehicles.

Some idea may be formed of the advantages conferred by the cable system abroad when it is known what has been there accomplished. It was first introduced into San Francisco with the object of supplying a communication between that city and its suburbs, but from the working of this initial line data were collected which showed that the economical results obtained were applicable to level districts. The above city had next a complete system of

cables all over it, and further, the city of Chicago availed itself extensively of the same arrangement. Other cities in America followed, in every case with complete success, notwithstanding the expensive form of construction adopted.

A few years ago a line was constructed in Edinburgh which was, for various reasons, the forerunner of a greatly improved system. Then followed one in Birmingham, which has been considerably extended, and now hundreds of miles of Cable tramway are to be found all over the country.

The main feature of the above plan lies in the central slot rail and trough in which the cable works and communicates its motion to the cars above it. This trough is made of concrete, the bottom of which is 19″ below the top of the rail, and its width 9½″, and in the concrete are bedded, at intervals of 3′ 6″, cast iron tube frames, to which the slot rails are bolted. The frames are all lined up in place before the conçrete is poured in to a thickness of 5″ at the sides and 7″ at the bottom, consequently the whole becomes a homogeneous mass which prevents any subsidence or closing in of the rails.

In the Edinburgh tramways, recesses, 50 feet apart, are made in the trough for the reception of the pulleys that support the cable, the spacing of the latter at points of curvature depending more or less upon the radii of the curves, and other varying conditions. All these recesses are connected to a drain pipe in such a way that no water can collect in them, and in addition to this, a subway is placed between two tracks which most conveniently and inexpensively enables the pulleys to be renewed or adjusted.

The *Track rails* are of the ordinary girder type, 6″ deep, and weigh 75 pounds per yard.

The *Slot rails*, which so vitally affect the good working

of the line, were designed to lessen the cost of tube construction by reducing its depth, and by forming in the rail itself a means of supporting the gripper in going round corners. These rails are of steel, 39 pounds per yard, and are fish plated on the outside only. The width of the slot has been made only $\frac{5}{8}''$, so that while not interfering in any way with vehicular traffic, it is still sufficient to do all that is required in the most complete manner.

The *Supporting pulleys* are 14″ diameter, and are made adjustable in the tube. These, for even the worst of the curves, being so arranged that the worn parts can be easily renewed, whilst the large diverting pulleys are built in segments so as to be removable in confined localities.

The *Cables* are of steel, and not only possess great flexibility and strength, but give a maximum amount of wear without fracturing the wires of which they are composed.

So far as the working gear is concerned, the *Gripper* holds one of the most important positions, since the successful working of the system depends very greatly upon this little detail, which transfers the motion of the underground rope to the cars through the opening in the slot rail.

The *Engines* for driving the whole system consist of a pair of high pressure horizontals, having cylinders 20″ diameter, and 40″ stroke, so arranged that they can either work both routes at the same time, or allow of one of them being disconnected without interfering with the other.

Taken as a whole, the Edinburgh Cable tramways are successfully worked under the following conditions:—

1. Over gradients as steep as 1 in 11.
2. Over perfectly flat roads.
3. Round small right angled curves.

4. Over old bridges with the crowns not 12″ from the road surfaces.

5. Two routes at considerable distances apart being worked by one engine at a station common to both.

6. Single lines with passing places.

7. Cars workable at reduced speed round curves.

In addition to the above, the cable routes run in conjunction with horse systems, and take on their cars. From what has been said on this point, it will be seen that the Cable system as a whole possesses valuable features which render it specially useful in localities where a sufficiently paying traffic is expected, if not already assured. As evidence of its appreciation in the Scottish Capital, we may add that only recently considerable extensions were made which have proved very advantageous.

Electric Tramways.

Electrical Traction, for both railways and tramways, is the latest of all, and judging by results we may expect for it a brilliant future. There are five great systems, each of which has its own special features, but that which concerns every one of them is the ease with which power may be derived from any existing steam engine, or from one of those in a work or factory whose surplus power may be sufficient to drive the necessary dynamo. The above systems are as follows:—

1. *Double-wire circuit.*

2. *Single-wire system*, using the running rails to complete the circuit.

3. The *Third rail system*, which has an insulated extra rail to carry the outward current, the return being made through the running rails, as on the Liverpool Overhead and other similar lines.

4. The *Conduit system*, in which the current is carried by an insulated wire, etc., laid in a channel between the rails or underneath one of them, the return being through the running rails.

5. *Storage battery system*.

The individual advantages of each of the above may be thus described :—

1. *Double Wire Circuit*.—By this arrangement, two overhead insulated bare wires are carried by span wires or brackets, which are in turn supported by poles, or by existing walls and buildings. There are few examples of this system, as these have been necessitated by very exceptional conditions; nevertheless, their working has been excellent, one wire being used to take the up, and the other the down service, cross connections enabling them to supplement each other.

An electric locomotive, taking up the current from two copper wires thus arranged, has been advantageously used for some time past at the works of a mining company. The gauge of the railway is 22″, and, as it runs chiefly underground, through a roadway in some cases only 32″ wide, it was found necessary to place the electro-motor with its shaft parallel to the rails, instead of transversely to them as would otherwise have been the case.

The electric current is generated by a dynamo placed about a mile and a half from the mouth of the shaft, and driven by a turbine actuated by a water fall, the former being also employed in driving ore dressing machinery.

2. *Single Wire System*.—In this case the current is led by an overhead bare insulated wire, whence it is usually collected by a wheel mounted at the end of a long arm, the wheel being kept in contact with the wire by means of suitable springs at the base of the arm. This is

termed the "Trolley System," which is extensively used in the United States, and has been adapted to English requirements very succesfully upon the South Staffordshire tramways at Walsall, and elsewhere.

The above system may be subdivided, according to the method of hanging the overhead wire, which, in many foreign parts, is kept directly over the centre of the car. In this country, the position of the former in relation to the latter varies considerably, the usual custom being to carry the wire on one side of the vehicle instead of above it, in order to allow of shorter brackets on the poles, as well as to avoid inconvenience to those in connection with the roof seats, as shown in the opposite view of the 1896 Hartlepool tramway by the Electric Construction Company of Wolverhampton. The methods of suspension are either by :—

a. Span wires carried by poles at either side of the street, or, when this is narrow, by rosettes attached to the adjacent buildings.

b. By side bracket poles; and

c. By centre poles for double track in wide streets, the surrounding circumstances in every case indicating the system to be employed with the best results.

3. The *Third Rail System*, though very successfully used on the Liverpool Overhead Dock Railway and elsewhere, has the extra rail placed very much in the way, and the risk of completing the circuit through any passing body coming in contact with it and either of the two running rails is so great that the system may be considered best suited to *fenced* railways or tramways.

4. The *Slot Conduit System*, which employs one or two copper or iron conductors, which may be of wire, rod, tube, or special section bar. The electric circuit is sometimes

double, there being then two conductors in the conduit, or single when the return is through the running rails. The conduit is placed sometimes under one of the running rails, and at other times in the centre, in any case, however, good drainage is essential for successful working.

HARTLEPOOL ELECTRIC TRAMWAY.

The *Closed Conduit* or *Sectional Contact System*, of which a number of short lengths of experimental line are in operation, is a modification of the above, but in all of these only the contacts or sections protected by the car are energised.

The great difficulty, however, that has been experienced is to provide that the sections or contact knobs shall be incapable of failure, earthed or cut out from the electrical circuit when not under the protection of the running car.

5. The *Storage System*, although only adaptable for use on tramways having easy gradients, has much to recommend it, as there are no wires in the way, or rails to be bonded, whilst the storage cells can be charged by any available engine during the night, or at any time when not required for other work, but even here there are disadvantages that cannot be set aside. These include loss of power in the cells; disintegration of their negative plates owing to the vibration of the vehicle which carries them; and, thirdly, the heavy weight of the cells. Here, however, recent discoveries have proved most useful in mitigating the last two evils.

Present practice in the United States shows conclusively that the Cable plants previously referred to are being rapidly superseded by Electrical installations, the reasons given being as follows:—

1. Electric cars are operating successfully in regular service upon gradients as steep as 1 in 10.

2. The Cable system only competes economically with the electric system when a three minute or quicker service is possible, or when the receipts average about £20 per mile per day, which few tram roads are able to maintain.

3. The electric system with overhead wires is more easily adapted to a growing city, and to extensions not contemplated at the outset.

4. Luxury in appointments, to satisfy public demand, is more readily and cheaply complied with on electric cars, the electric heating and lighting of which compare favourably with coke stoves, and oil or gas lamps.

5. A greater car mileage per day with the same safety speed limits can be obtained with electric cars, whose velocity can be rapidly accelerated and adjusted to suit the conditions of each street and its traffic, whereas, on the other hand, the cable car can neither make up lost time in running, nor can it be backed, if required.

6. Breakdowns on electric lines are almost always limited to the half mile sections, and do not disorganise the traffic on the whole route, as in the cable system.

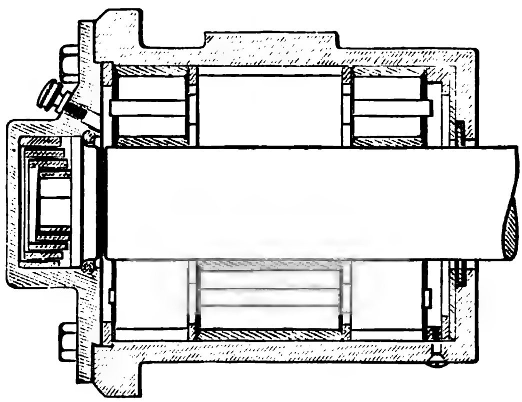
7. The first cost of installation is much less than in the cable system, which is important, especially where short leases exist.

The amount of tractive force required to keep a tramcar moving with a uniform velocity on level roads has been found by a large number of experiments to be very much in excess of that required on railway lines, and is usually not less than 20 lbs. per ton on clean rails. The additional resistance, too, due to dirt from the street becoming caked in the grooves, is sometimes so serious as to cause the traction on a level to rise to 30 and even to 50 lbs. per ton, hence the necessity for employing some system which will help to compensate for this unavoidable friction.

Great improvements have lately been made in the axle bearings of cars, which in many cases have had rollers fitted to them with the best results. These bearings have been tried from time to time during past years, and although promising well at first, defects in construction caused their abandonment. Recently, however, a new arrangement has been used very satisfactorily and extensively in America, on railways as well as on tramways, about 140,000 miles having been run by a car on the former without any appreciable wear in some of the bearings. Experiments have also been made to ascertain

the amount of coal saved, and the tractive power required, the results of both of which have been extremely gratifying.

The annexed views illustrate one of these axle bearings, as fitted by Messrs. Siemens Brothers & Co., to cars on the Ryde electric and other tramways, the mean power experimentally required to draw a loaded car on very many double runs having been reduced by 24 per cent., whilst the speed was increased by 20 per cent., and the starting effort diminished to less than half of what it had formerly been.

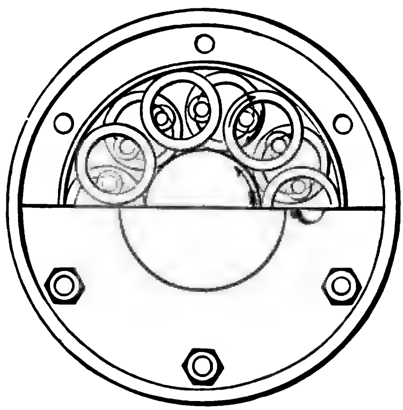


TRAMCAR AXLE, TUBULAR BEARING (FIG. 1).

The bearing, as shown, is 3″ diameter, the steel tubular rollers being $2\frac{1}{32}$″ diameter externally, and $1\frac{1}{8}$″ internally. These are made by the peculiar Mannesmann process to ensure the greatest crushing strength, the central tubes being twice the length of the others, and overlapping each other, as shown in Fig. 2, to allow small pins to link them all flexibly together, the whole being placed within a steel cylinder supplied with oil, and closed at each end to make the chamber dust proof. The great advantage of having bearings such as these is due to the fact that

resistances from bad bearings are *continuous*, whereas the others are only intermittent.

In the form of general remarks, we may add that, as cheap travelling in cities is immensely taken advantage of by the public, every facility for supplying it should be placed before them. There were in the United Kingdom, in 1895, 960 miles of tramways, representing a capital expenditure of £14,104,152, and carrying annually 598,289,509 passengers. The railways, on the other hand, with a mileage of 20,000, representing a capital expenditure



TRAMCAR AXLE, TUBULAR BEARING (FIG. 2).

of £990,000,000, only carry 900,000,000 passengers annually. A large field exists for additional tramways, as well as for the extension of present systems. It is very evident, however, that some other method of traction than that of horses must be employed.

This is proved by results, shown by the fact that the city of Liverpool, with a population of 518,000, is provided with a system of *Horse* tramways 61 miles in extent, by which about 18,400,000 passengers are carried annually at

a cost of 90·69 per cent. of the gross receipts. On the other hand, the city of Boston, U.S., with a population of 600,000, has a system of *Electric* tramways 270 miles in extent, which carry about 115,000,000 passengers each year at a cost of 55 per cent. of the gross receipts. In July, 1896, Chicago had 342 miles of tram line, of which 270 were electric, horse traction having practically disappeared, and by the end of the above year 58 additional miles had been laid—all electrical.

According to a recent Report published by the Board of Railroad Commissioners for the State of Massachusetts, it may further be said that, in 1888, horse traction was the only means of tramway propulsion adopted in that State; but in 1894, electric motive power was exclusively used. The nett earnings per passenger carried had increased by 62·5 per cent. from 1888 to 1894, and at the same time, the nett earnings per car mile, and per mile of road, had advanced respectively 73.5 per cent. and 57 per cent.

Facts like these clearly indicate the superior economy of this method of traction, and also the quick appreciation by the public of the increased facilities for transit thus provided for them.

The electrical portion of this chapter has been the most difficult to work up, owing to the peculiar nature of the subject. In this, however, we have been very materially aided by the Electric Construction Company previously mentioned, who have most kindly supplied particulars of some of their latest undertakings at home and abroad.

CHAPTER XIII.

AMENDED LIGHT RAILWAY SYSTEM—GOODS TRANSPORT ON ROADS.

Light Railways—Cheap Railway Transport—Manual Treatment of Goods—Parliamentary Expenses of a Proposed Line—Advantages of the Light Railway System—Its Difficulties—Sources of Economy in Construction—Level Crossings—Continental System—New Methods of Road Transport—Particulars of Improved Road Locomotives—Their detailed Arrangement—Their Road Performances—Their Stand-by Employments—Road Construction—Compound Steam Road Rolling Engines—Road Traction as a Feeder to Railways—Obstacles to be overcome.

HAVING described in the last two chapters the peculiarities and construction of Portable Railways and Tramways, we must now make a few remarks upon the *Light Railway* and other systems of Transport. By the italicised system, we mean one that, while it comes next in order to the greater enterprises that practically rule the land transport of the world, is in itself of immense value as a cheap feeder or tributary to these lines, if not holding an independent position of its own.

The subject of *Light Railways* has now become of special importance in view of recent movements in places throughout the globe which have at last been thrown open to the skill and enterprise of the engineer, so that the fertile valleys and rich mineral treasures which are known to exist in various localities may be fully utilised.

When the ancient Romans conquered a new territory, their first efforts were bestowed upon the formation of

roads that in many instances fixed the sites of some of the cities. So, too, has it been with the light railways, upon which the welfare of new countries so much depends. Here, however, people may naturally enough be led to form wrong conclusions at the outset. For instance, they may on the one hand, attach undue importance to a standard gauge line at a time when no such importance exists, or is likely to exist for a long period. On the other hand, they may fancy a narrow gauge railway too insignificant to do much good. Thirdly, great misconceptions may arise regarding the relative cost of construction and maintenance of each system. It is on all these points, therefore, that every feature in the case has to be carefully considered before a just estimate can be formed of the respective advantages of each system when applied to a particular district.

The narrow gauge, or 2′ 0″ to 3′ 6″ railway, is highly beneficial in new countries, and also in certain parts of old ones which cannot maintain a standard line on account of its expense. The whole subject, however, in its infinitely varied and sometimes complicated forms, has been so fully investigated and discussed from every point of view, that its past and present aspects need not here be referred to, but as it has become evident that this system of transport will soon be worked more extensively than ever under improved conditions, we shall devote a few remarks to these as we proceed.

To such a state of perfection has the railway system now attained that further progress seems hardly possible. The speeds are high, the rates extremely low, and the convenience great. When, however, we come to the handling or breaking of bulk of goods at stations, we find that expenses are incurred which, in the opinion of people best

capable of judging, are unnecessarily heavy, hence it is the aim of those most interested to introduce a cheaper and better system. The importance of this will be seen when it is known that large tracts of country, especially in the agricultural and manufacturing districts, are practically destitute of sufficiently inexpensive means of transport for their productions from the source of origin to the point of delivery owing to the cost of transhipment, which otherwise might be greatly avoided.

To show how cheaply merchandise can be transported by rail alone, it may be mentioned that during the Manchester Canal Inquiry before Parliament, it was stated that the cost of carrying a ton of goods from Liverpool to the above city was 5d., or one-sixth of a penny per mile, whilst in the United States this had been reduced to one-tenth of a penny for long run averages.

While, therefore, the cost of rail transport was almost nominal, that of handling was excessive, and, as an excellent example of this, we may add that not long ago when the Mansion House Committee of London endeavoured to prevent the London and North-Western Railway Company from raising certain rates, the reply was that their rates had not been increased, but that the handling was 5 per cent. more expensive than when these were fixed, and also that in the Metropolis the advance had been as much as 20 per cent., thus clearly showing where economy might be obtained.

Before anything can be done towards the construction of a new line, enormous Parliamentary expenses have to be incurred, all of which may eventually be lost if the Bill is rejected. Even if it is passed, the promoters may be exposed to considerable outlay by the acquisition of land and property under what may often be very unfavourable

circumstances. Recent events on the Continent have shown conclusively the great value of light railways to agricultural and trading communities, owing to their economical construction, and also to the absence of those stringent laws which in this country have so long had a very depressing effect upon similar schemes.

A light railway has very much to commend it as a cheap feeder of the main lines, and as a great convenience to those through whose property it passes. It should, however, be a single one, with passing places where required, and also made in suitable districts to follow as nearly as possible the undulations of the ground it has to traverse, for the sake of earthwork economy. This, however, cannot be done unless the private and many of the public roads are crossed on the level.

The necessity of this may be gathered from the fact that if such an arrangement is not permitted, and the road remains as it was, the railway must either cross it by means of an embankment, or pass underneath it through a cutting. As also, in some parts of the country, the roads are very numerous, a railway thus constructed may hardly be well clear of one of them before it approaches another, consequently the earthworks become costly undertakings when otherwise they might hardly exist.

The importance of having level crossings cannot be over-estimated when their economy is considered. The mere cost of a bridge is a trifle compared with that involved by earthworks, and it has now become evident that if suitably cheap additional light railways are to be constructed in England, these crossings must be allowed, subject, of course, to stringent regulations to ensure complete safety. This question affects everything connected with the construction of gradients, bridges, and approaches,

which may or may not be required, according to the leniency with which the Company is treated by the Government authorities.

Independently of these, however, there are other sources of economy that may be drawn upon to produce the desired result. Stations and platforms, etc., for instance, may be of the simplest possible character, and the ordinary signalling arrangements may be simplified or even abolished for the sake of economy, bearing in mind all the time that these railways are intended only for *goods traffic* at slow speed.

As recent discussions regarding their great usefulness and convenience are of great importance, owing to the interest in them that has been awakened throughout the world, it may be well to state that some of our best lessons in this branch of engineering have been derived from those foreign countries where the system is now fully developed and found most profitable.

In Belgium, Italy, and other parts of the Continent, for instance, these lines are extensively used on the public roads, the difference being that the locomotives employed drag after them five or six cars instead of only one, as on tramways. No doubt some of these roads have originally had awkward gradients and curves, or have even been circuitous; nevertheless a few deviations, or widenings at certain points, with perhaps the addition of one or two light steel bridges, have done all that was needed.

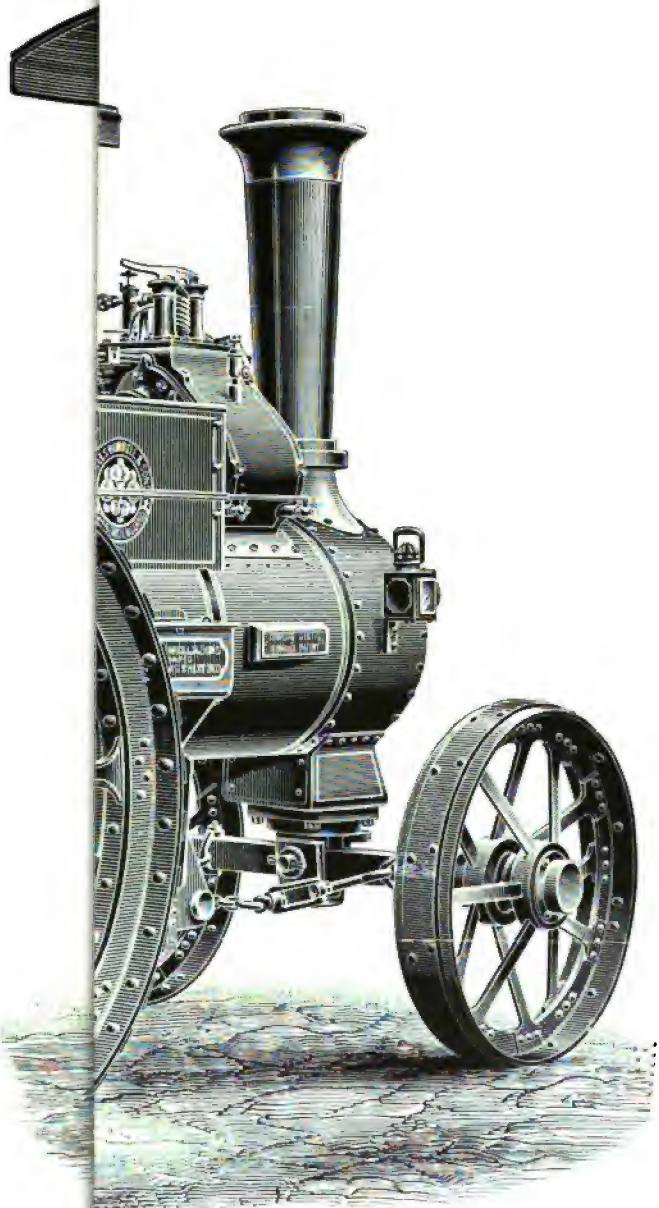
In England, circumstances have so much altered of late, that not only has an extension of the light railway system under greatly ameliorated conditions become necessary, but other methods have been proposed with the object of ramifying a district still more completely with the handiest possible means of transport, one of which is the

"Plateway system" of Mr. Alfred Holt, and the other the "Lurry railway" of Mr. E. R. Calthrop.

The former proposed to lay down plate rails on the high roads, so that wagons could be easily hauled along them by traction engines, and thus collect and deliver goods at many points over large areas untouched by railways. The latter scheme provided for the similar transport of loaded vehicles on supporting carriages or lurrys, the vehicles being lifted bodily upon the main line wagons at stations without breaking bulk, and, on reaching a terminal or other station, being conveniently enabled to continue their journey direct to the user, either along roads or streets by horse power or by mechanical agency. No doubt the above plans contain the germs of future success, in some form or other, capable of suitable development in course of time. With this in view, therefore, we may turn to the *Road Locomotive* branch of transport, which has proved universally successful, though not so well known to the general public as it should be.

The engine itself is at least 100 years old, Symington, of Edinburgh, having been engaged in 1788 with experiments upon this new method of transport, which has passed through many stages of development during the last forty years, especially by Messrs. Charles Burrell & Sons, of Thetford, and John Fowler & Co., of Leeds, both of whom have brought the latest and best practice to bear upon this branch of engineering. The main object of the invention was to reduce the cost of haulage on roads, and in subsidiary fashion to provide a motor capable of varied application to work in any locality to which the engine in its portable form may be taken. This has been accomplished most successfully, as we shall endeavour to show.

The adjacent folding Plate of a *Compound Spring*



Mounted Road Locomotive, by Messrs. Burrell, gives a very clear and comprehensive view of its general appearance.

The *High-pressure Cylinder* is placed diagonally over the low-pressure one, so that the piston rods of both can be connected to one crosshead, the slide valves being coupled together and worked by one link motion. By these means a much simpler arrangement is obtained than with the ordinary two crank system, besides possessing other advantages.

The *Boiler* is of the most approved locomotive type, the working pressure being 160 pounds per square inch, and the hydraulic test pressure 320 pounds. It can also be arranged to suit firing by means of wood or other materials, in places where coal is expensive.

The *Crank Shaft* is made from a single round bar bent by hydraulic pressure into shape without welding, the pin having the same diameter as the bearings, which, as in all other similar cases, is not only good for wear, but indispensable for strength. Another peculiarity is that the keys for the four driving pinions are worked out of the solid metal and case hardened, instead of being treated in the ordinary way.

The *Brackets* for carrying the crank shaft, countershaft, and main axle, are so fitted to the horn plates which support them, that all straining of the boiler and consequent tendency to leakage is avoided.

The *Governor* is very powerful and sensitive, and at a high velocity, actuates an equilibrium throttle valve which regulates the speed of the engine.

The *Feed Pumps* are placed in view of the driver, and all the other engine gear has been designed not only to produce the best results in working, but the greatest economy in maintenance and overhaul.

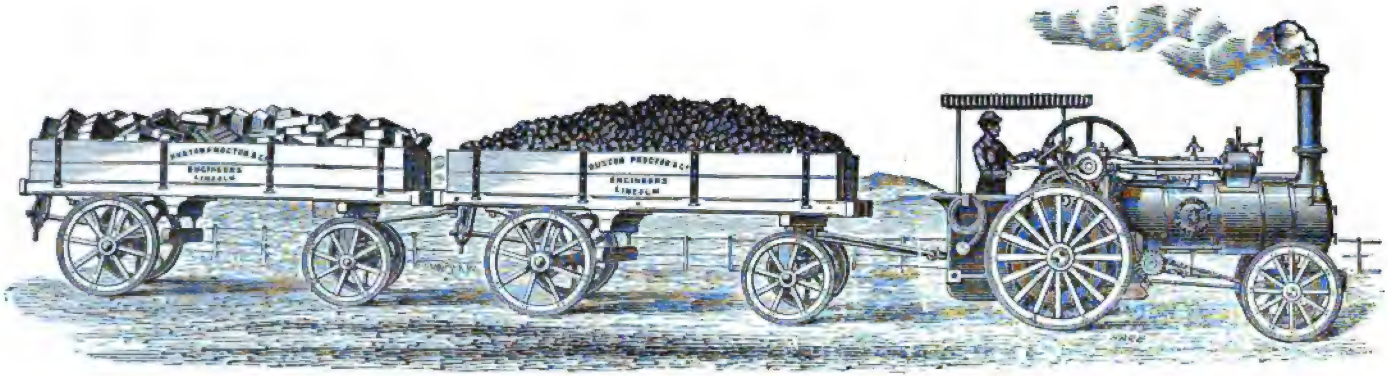
The *Water Tank and Coal Box* are fitted with all the necessary appliances as shown in the illustration, the coiled flexible pipe at the side being used for supplying water from any adjacent source.

The *Wheels* have their axle bearings so fitted with specially devised springs as to produce the smoothest action in running.

The crank shaft of the engine is supplied with pinions of different diameters gearing into suitable wheels on the countershaft, a pinion at one end of which drives a large wheel on the main axle, thus communicating motion of four different velocities to the whole structure up to that of 20 miles an hour if required. Nearly all the working parts are of steel, and embody the latest improvements that past practice has developed.

The *Wagons* are of timber, usually of six and eight tons capacity, the sides being made with hinges for letting down purposes, and the ends firmly secured in iron sockets for ready removal if necessary, so that the wagon may be adapted at once to the transport of any lengthy material. The front axle is so made to swivel that two or three wagons will follow the engine round any curve in each others wheel track, while the draw-bar is fitted with volute springs to avoid the wear and tear caused by road irregularities, etc.

The opposite illustration shows a portion of a complete Road Transport Train as manufactured by Messrs. Ruston, Proctor & Co., of Lincoln, which will explain itself. Although the wagons shown in the view are of the standard design and construction, the engine may be attached with equal facility to any kind of wagons, either of the great travelling show or menagerie order, or a long train of farmer's wagons loaded in every conceivable



ROAD TRANSPORT TRAIN.

manner, but nevertheless drawn in every case most satisfactorily on their journey.

With regard to the *performances* of Traction Engines as a class, we have varied information supplied by the users which helps to throw light upon the transport schemes previously mentioned, or on any others of similar nature.

In the first place, we find that Messrs. Burrell's engines will draw loads of about 50 tons up hill or down hill, along a high road, and under every possible condition, the speed being regulated to suit the load and the nature of the country. Recent improvements have greatly added to the value of these engines, one of which, for example, of eight horse-power, was able to draw seven wagons weighing 40 tons up hills where the gradients ranged from 1 in 17 to 1 in 11, 25 horses having previously been required. The same firm also manufactures a special class of engine for driving dynamos and hauling the roundabouts of travelling showmen, many of which are now in use.

From the employers of Messrs. Fowler's locomotives we have many similar reports of which the following may be given. By means of an 8-horse power engine, the Farnley Iron Co. had the ordinary cost of carriage reduced to 5d. per ton less than it had previously been by ordinary cartage, but for heavy metallic weights, the original transport cost of fully £5 by horses was reduced to £1 15s. by steam traction. In another case the cost of carriage was three farthings per ton per mile, and so on.

One of the most extraordinary performances was that of hauling, by means of a Fowler 8-horse engine, eight tons of wool a distance of 40 miles across a roadless part of Australia, and afterwards climbing steep slopes and traversing the very worst of roads to the point of delivery. At another time, this engine was sent in a time of drought

300 miles up the country, and for irrigation purposes was made to discharge water from a lake at the rate of 2000 gallons per minute, night and day, for a long period. The last important recommendation out of very many others comes from the travelling show, steam roundabout, and switchback fraternity, who found that the cost of direct transit of their apparatus was from 50 to 80 per cent. less than by rail.

The standby occupations of first-class road locomotives are very numerous, since, when not employed upon their own special work, they can be used for various agricultural purposes, and as main driving engines of a generally useful character, including the working of a dynamo which can be easily attached to the front of the boiler.

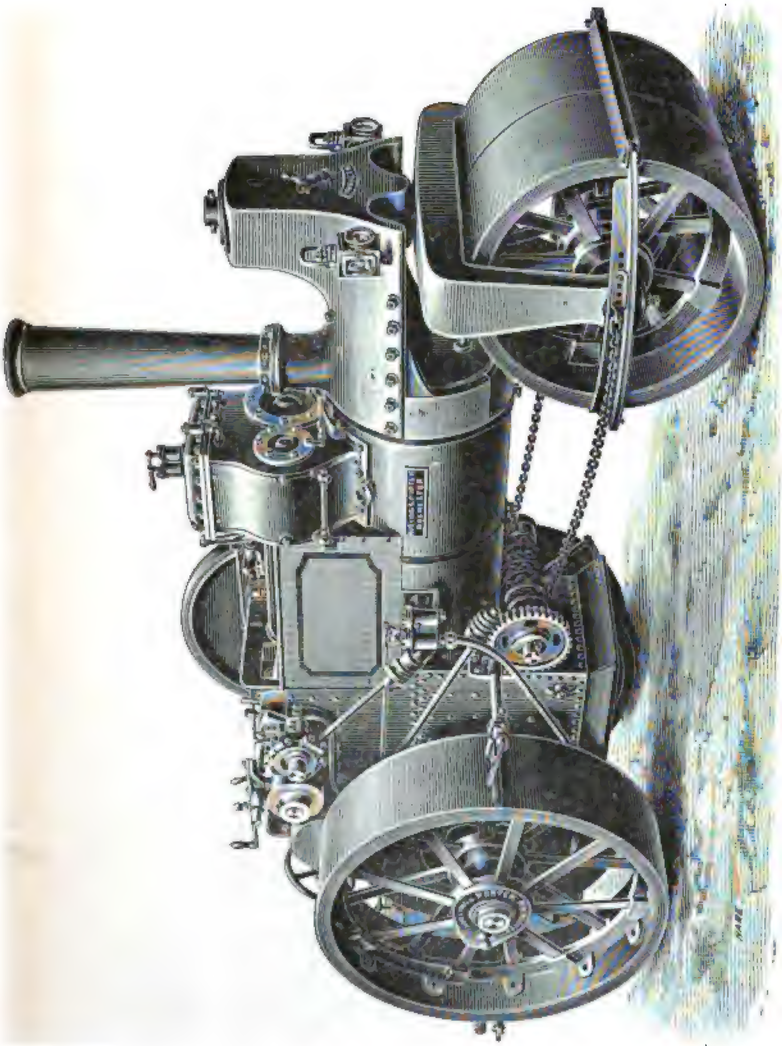
For the extended application of these engines in the more fully economised transport of the future, it will be necessary, in many places, to make alterations in old roads, and also to construct new ones, the solid substructure of which can only be obtained by careful treatment. In the best practice the roadway is excavated, graded, and properly formed to a depth of 14 inches from the level of the gutters, with a cross section similar to that of the road when finished. It is then thoroughly and repeatedly pressed down with the steam roller, all depressions being carefully filled and rolled before the stone is put on. On the bed thus formed and consolidated, a layer of stones eight inches thick is set by hand, and rammed into its place by sledge hammers, all irregularities of surface being broken off, and the interstices wedged with pieces of stone. An intermediate layer of broken stone, of a size not exceeding three inches in diameter, is then evenly spread to a depth of four inches and thoroughly rolled, half an

inch of sand being similarly pressed into it. Finally, a binding of clean, sharp sand is applied, well watered, and thoroughly rolled, until the surface becomes firm and smooth, the superfluous material being then removed.

An example of one of Messrs. Aveling & Porter's *Compound Steam Road Rollers*, for performing the above work, is given opposite, and although it possesses some of the leading features of the traction engine, it much differs from it in others, especially in the wheels, which have very massive and broad rims. These not only roll a road to perfection, but are in many cases so fitted with removable spikes in the driving wheels that, when required, the old surface can be disintegrated. As will be noted, the front wheels are so flexibly arranged as to at once accommodate themselves to the transverse and longitudinal curves they have to pass over.

The compound arrangement of the cylinders, while ensuring fuel economy on the one hand, produces the much desired silence in working on the other hand, owing to the very low pressure of the steam exhaust from the chimney. In short, these engines, taken as a whole, are admirably adapted for their special and severe employment, the usual sizes being of 6, 8, 10, 12, 15, and 20 tons capacity. If supplied with an extra set of wheels suitable for traction work, they can also be utilised for the transport of road surface material from point to point, and also for driving stone-breaking or other machinery.

As a feeder to railways the road locomotive system has shown itself to be unequalled, as it may be used in any place where horse traffic can be employed, and can also perform work under many difficulties where horse traction is impossible. Its chief drawbacks have been due to legal restrictions regarding speed, which caused heavy slow



COMPOUND STEAM ROAD ROLLER.

running engines and ponderous traffic to be preferred to those of a quicker and lighter nature. Owing, too, to the bad state of some country roads, injury to their surface has occasionally resulted. Now, however, amended legislation has greatly rectified these evils. Although much has been done in these respects, much more remains to be done. Our railways flourish, why not our highways too, when, as we have tried to show, it can be done so easily, with machinery of every description and of the most advanced types within easy reach, and capable of extensive and varied application to the wants of large as well as of small communities?

CHAPTER XIV.

WORKS OF THE LONDON AND NORTH-WESTERN RAILWAY COMPANY, AT CREWE.

Their Vast Extent—Their Origin—Their Engineers-in-Chief—Arrangement of the Buildings—Steel Works and their Machinery—Rolling Mills—Manufacture of Rails—Weldless Wheel Tyre Machinery—Forge and Plate Rolling Department—Forging Machines for Repetition Work—3,000 Ton Hydraulic Press—Advantages of the System for Forging and Stamping—The Accumulator and Intensifier—Useful Portable Machines—Treatment of Heavy Scrap Iron and Steel—Powerful Steel Sawing Machinery—Gas Furnace Heating of Metals.

As all railways more or less owe their successful management and maintenance to the Works where their renewals and repairs are executed, we now propose to describe a model establishment of this class, which is the largest in the world, and which has long been considered of unique interest by Royal and distinguished personages who have visited this country, and by engineers and railway officials from all parts of the globe. Whilst describing it, our remarks are also intended to give a good idea of what to some extent takes place in other works of similar nature though of lesser degree.

If the vast establishment at Crewe merely constructed as well as repaired the engines and rolling stock of the line, it would be similar to many others, but when the manufacture of *materials*, and of every *mechanical appliance* connected with railways is added, it will be evident that these works stand alone in their extent. By the Italicised terms we mean rails, chairs, and sleepers—plates, bars, and angle,

etc., irons, for engine frames, boilers, tenders, ships, bridges, and so on—mill gearing, and engines of all kinds for the outside and inside requirements of the various lines —signalling apparatus—steel and iron castings of every description—brass founding, and copper work—timber work on an extensive scale—the manufacture of bricks at the rate of about 5,000,000 per annum, and the shaping of stones for station buildings, offices, warehouses, etc., throughout the whole of the London and North Western system.

As may readily be supposed, the workshops in which the above operations are conducted require a large amount of space. This may be gathered from the fact that while some of our largest private establishments occupy 40, 50, 60, and even 70 acres of land, the Crewe Works require a much larger area, and this, too, notwithstanding the existence of large wagon works at Earlestown, and carriage works at Wolverton, besides minor repairing shops at Willesden, Rugby, Carlisle, and Longsight, all of which, however, receive their iron and steel from Crewe.

These remarks will give a fair conception of the gigantic series of operations carried out at the famous establishment we recently had the pleasure of critically surveying, through the kind permission of Mr. F. W. Webb, and under the pleasant and profitable guidance of one of the staff.

As information concerning the latest and best means employed for maintaining, in efficient order, a great railway system over which some of the heaviest and most continuous traffic of the world is carried with marvellous safety, we thought it advisable thus to specially gather important facts. The term "marvellous safety," may perhaps convey a false impression regarding the necessity

for so many renewals and repairs, owing to the almost entire absence of collisions, breakdowns, and smashes of every kind. It must be remembered, however, that so highly pressed has everything now become, in speed, and in other ways, on the railroad to which our observations are directed, that the ordinary wear and tear of every day practice is quite enough in itself to keep the Crewe and the other establishments fully occupied.

Further, it may be said, that a very large amount of the employment so continuously given to these works, is created by a principle which permeates the whole of Engineering practice on land and sea, and which requires the immediate expulsion of every faulty part *before* it breaks and does mischief. Many steamship Companies have thus been saved from terrible disaster, because a rigid examination of main shafts, etc., in port, after a few years' service, has revealed flaws in the metal which were so menacing as to render their removal desirable.

So also is it in railway matters, as a cracked tyre the necessary removal of which has been pointed out by test hammering at a roadside station; a crank or any other axle that looks unsound; boilers that need repairs; valve faces that require planing; cylinders that want re-boring; bearings of all kinds that need re-adjustment; rods that have been damaged; not to mention all the minor details of the rolling stock and fixed plant, and everything else connected with the permanent way and its fixings, etc., throughout the whole system. All these repairs and renewals, in addition to the new engines, tenders, and other matters constantly in hand for nearly 3,000 miles of double and sometimes quadruple line, will at once account for the immense proportions of the Works at Crewe.

From 1830 to 1842, the extension of the railway system

in England was astonishingly rapid, but in the latter year, the Liverpool and Manchester, the Manchester and Birmingham, the London and Birmingham, and other lines, including the Grand Junction, became united in one comprehensive association entitled the "*London and North-Western Railway Company*," which soon afterwards realised the importance of selecting a central point for conducting the various operations connected with the newly combined lines. In 1843, therefore, the Grand Junction Repairing Works, which up to this period had existed at Edge Hill, Liverpool, were transferred to a new locality, and from that time to the present the development of the little village of Crewe has been by leaps and bounds, from a population of 203 in 1841, to one of about 35,000 at the present time.

In 1843, the works covered not quite three acres of ground, now, however, they occupy 116 acres, and have in consequence transformed the village of the past into the large and prosperous town it has now become. At present, they employ 7,000 men, and in addition to these, a large number of hands connected with the line are located in the district, the total number employed by the Company over its whole system being at least 65,000.

The first Locomotive Superintendent at Crewe, was a son of Mr. Trevithick, who was succeeded in the year 1857, by the late Mr. Ramsbottom. In 1871, the post of Chief Mechanical Engineer and Locomotive Superintendent became occupied by Mr. F. W. Webb, who, after directing for some years the Bolton Iron and Steel Works, returned to the establishment in which he had formerly been apprentice and acted as manager, and where he has subsequently introduced at least fifty useful patents for railway and rolling stock improvements.

As the greater portion of the buildings is of recent erection, every attention has been paid to their arrangement in accordance with the best modern practice. This has provided for greater proportionate area, better light, all the most improved methods of lifting and transporting heavy weights, and also a simple but effective style of brick and stone architecture, which gives a pleasing appearance to otherwise unattractive exteriors.

The *General Offices* are of the most spacious description, and occupy a handsome building two stories in height, and several hundred yards in length, embellished with evergreens, which, along with an adjacent shrubbery, produce quite an artistic effect. The above edifice contains the Drawing Offices; the Accountant's, Running, and Signal Offices; the Photographic Studio, and Laboratory, etc., and the private rooms of Mr. Webb and the numerous heads of various departments. Here, too, full occupation is found for hundreds of draughtsmen, clerks, and others, who are engaged not only in the scientific and commercial branches, but in keeping exact practical records of engine performances, coal consumption, works expenses, etc., and the general expenditure connected with building, repair, and cost of working and maintenance, of all the engines and machines throughout the whole system.

Everything is done in regular order, even to the guidance of a visitor over the premises. In this way, we passed from shop to shop, the first department being the *Bessemer Steel Works*, where the manufacture of this material is carried out in all its completeness. This proved specially interesting, owing to the employment of a class of machinery not to be found in any other railway establishment, the London and North-Western being the only Company that rolls its own rails, plates, bars, etc. Here,

too, we found a profusion of wheels, tyres, axles, and other miscellaneous gear in the rough state.

The steel making plant consists of four egg shaped receivers or converters, each holding 5 tons, and arranged in two groups, with the cupolas behind them. The pig iron is first melted in a cupola to which the air is supplied by a blower, after which, the liquid metal is run into an immense ladle, and conveyed on rails to the receivers. These latter are lined with ganister, in the bottom of which are numerous small holes through which air is injected upwards through the fluid mass, the oxygen of the air combining with and eliminating the carbon of the iron, and keeping up a fierce combustion until the whole of the impurities are ejected. The blowing is continued for fifteen or twenty minutes, amidst showers of sparks, and a vigorous outburst of flame through the upturned spout, until the metal is thoroughly decarbonised. The blowing is now stopped, and a specified quantity of "spiegeleisen" —an iron highly charged with carbon and manganese previously melted in a furnace—run into the converter to combine chemically with the decarbonized iron.

After this the vessel is turned down, and the newly formed liquid steel poured into a ladle carried at the end of a hydraulic crane which swings round the circumference of the casting pit, the steel running out through a small orifice in the bottom of the ladle into cast iron moulds, thus forming ingots ready for use. The air is supplied to the receivers by a pair of horizontal blowing engines of 450 horse-power, the steam cylinders of which are 36″ in diameter, the air cylinders 48″ diameter, and the stroke of each 5 feet.

From the moulds the ingots are taken when solidified, and then *reheated* before being passed on to the mill, as their

exterior becomes too much chilled for satisfactory rolling. It will therefore be seen, that by reheating the ingots in specially prepared furnaces, the excess of heat interiorly stored up by the semi-fluid metal becomes so distributed throughout the mass, that the ingot can be easily roughed down in the cogging, and finished in the rolling mills.

The *Rolling Mill* was a splended invention, since by its aid an infinite variety of plates, bars, etc., can be rapidly, economically, and exactly finished to specified sections and weights, that cannot be done in any other way. To see a mill, however, in its unique development, one must visit establishments such as those of Sir John Brown & Co., and Messrs. Cammell & Co., of Sheffield, whilst rolling an armour plate of say, 30 tons, and 18″ thickness. At such times, the scene, with all its weird like surroundings is most impressive, owing to the immense mass of red hot metal, which requires many attendants, colossal machinery, and special precautions in manipulation with the object of avoiding serious accidents.

The *Rail Mill* at Crewe is one of the most important sections of the works, as it contains machinery capable of manufacturing 45,000 tons of rails per annum. Broadly speaking, Rolling mills consist of two distinct classes, namely, those for plates, and those for bars. The former consist of two pairs of rolls ordinarily about 20″ to 36″ diameter, and from 4′ 0″ to 9′ 0″ in length, their distance apart being so regulated by screw gear that when the roughing rolls of the first pair have done their work, the finishing rolls of the second pair gradually reduce the plate to the required thickness.

Bar rolls are of endless variety to suit angle, tee, channel, etc., irons, and also rails, which at Crewe are in great demand for extensions as well as for old lines. Here,

however, each pair of rolls is grooved to suit the different stages of manufacture, beginning with the original billet and ending with the finished production.

Formerly, with driving engines constantly going in one direction, it was usual to return the work in progress over the top roll from back to front, before re-rolling. To avoid this inconvenient system, however, Mr. Ramsbottom introduced those of the now popular Reversing type. As these engines are exposed to very severe usage, especially in steel works, owing to the low temperature at which the metal is rolled when compared with iron; to continuously sudden reversals, and to unforeseen irregularities in the work of the mill, it is necessary to make them of enormous strength and power. Some idea of this may be gathered from the following proportions of a pair of cogging or roughing mill engines made by Messrs. Galloway.

Cylinders, 42″ diameter, by 5′ 0″ stroke.

Crank shaft bearings, 16″ diameter.

Ratio of power increasing spur gear, 2½ to 1.

Teeth of the wheels, 24″ broad, and 8″ pitch.

Weight of engines, 195 tons.

Finishing engines by the same firm, are made with cylinders up to at least 56″ diameter and 6′ 0″ stroke, the crank shaft bearings and pins being 21″ diameter. The valves are actuated by the Joy gear and the total weight of the engines is about 270 tons.

The manufacture of rails at Crewe is most instructive and interesting, and with the mills driven at the rate of 45 revolutions per minute by 700 horse power engines, an ingot about 3′ 0″ long by 10½″ square, is reduced in the roughing rolls and completed in the finishing rolls as a 30 feet rail, weighing 85 to 90 pounds per yard, in about two minutes. Upon leaving the mill it is carried over a series

of live rollers to a *Hot Steel Saw*, which cuts it to the exact length, allowance being made for contraction in cooling.

Usually, these saws have a diameter of 30″, and a velocity of 1,400 revolutions per minute, the table which carries the bar to be operated upon being feed traversable either by means of a lever or by a hand wheel and screw. Subsequently, the rail is straightened, and passed on to a duplex machine, that, with automatic adjustment and interchangeable accuracy, drills the fish-plate bolt-holes at one operation.

Having described the manufacture of rails, let us now turn to that of the *Wheel Tyres* which run upon them, and which differ very materially from the original welded hoops of bar iron. Noting the defects of this system, Mr. Ramsbottom conceived the happy idea of initiating a better one, with the object of manufacturing *weldless* tyres of Bessemer steel. The process as it stands to-day is so simple that by means of special machinery immense quantities of faultless tyres are produced with an economy otherwise unattainable. The quality of the metal, too, is so much improved by the manipulation it undergoes that it is enabled to withstand satisfactorily the most severe tests that can be applied to it.

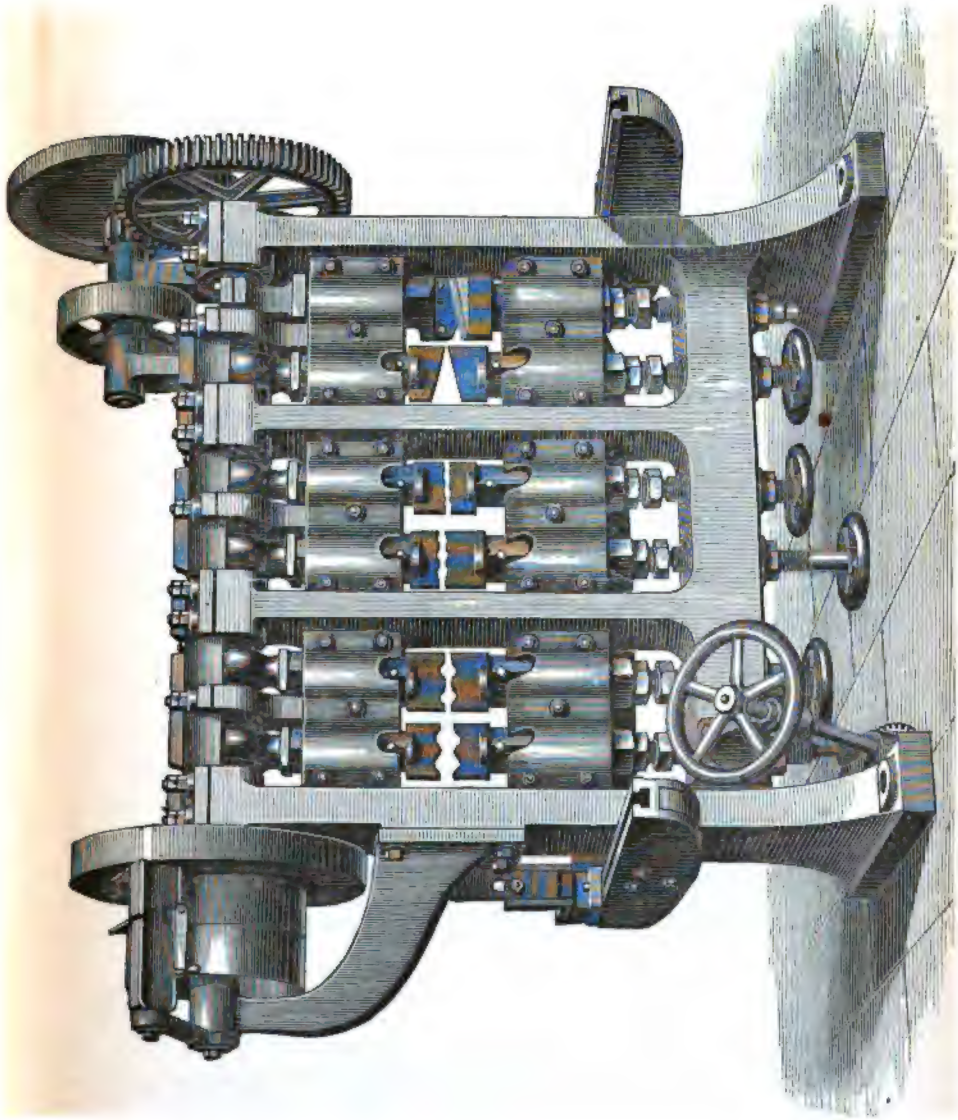
A visit to the neighbouring *Forge and Plate Rolling Department* is most instructive, eight steam hammers of 15 hundredweight to 8 tons, as well as a 30 ton and also a 10 ton duplex hammer being found very useful. Each of the latter consists of two blocks of metal, driven horizontally to and from each other by steam pressure, whilst resting upon wheels which travel upon rails. It therefore follows that an enormous compressive force is thus given to a mass of hot metal placed between the blocks without the vibration incidental to hammers of the vertical type.

After everything had been done to develop the steam hammer to the utmost, it still proved incapable of making multitudes of small details with the desired speed, or the heaviest forgings with sufficient internal soundness. Hence it has now been superseded by special machinery for the former, and by hydraulic presses capable of pressures from say, 1,000 to 16,000 tons for the latter, which are extensively made by Sir Joseph Whitworth & Co., and Messrs. Tannett, Walker & Co.

The first named operations are performed by means of *Forging Machines*, a very useful specimen of which by Messrs. John Hetherington & Sons, is shown opposite. These machines are fitted with a series of hammers so graduated in form as to produce unerringly and with great rapidity the required details, the hammers being worked by eccentrics on the main shaft at a speed of about 600 revolutions per minute. The bottom blocks, or anvils, are adjustable vertically by hand screw gear to such an extent that forgings, in large quantities, can be automatically finished to an exact size with the least amount of trouble. On the right side of the machine two pairs of shearing blades are placed, these, however, by means of separate gearing, are driven at the necessarily low speed of 40 strokes per minute.

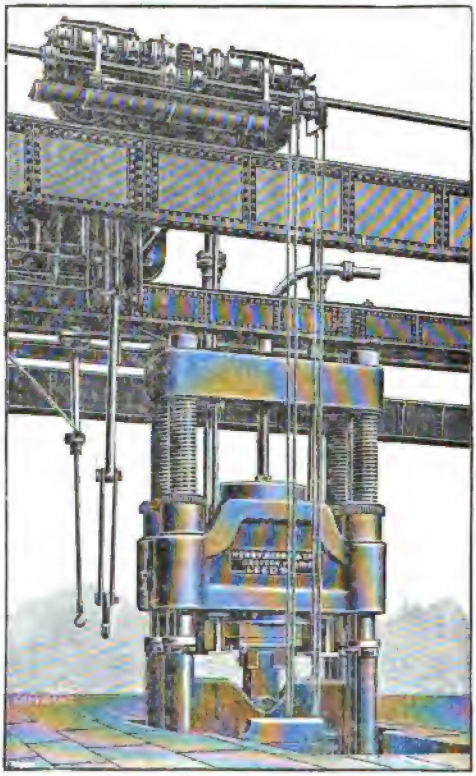
For very heavy work, the *Hydraulic Forging Press* is most successfully employed, its usefulness depending chiefly upon the fact that the pressure is so great, and so steady throughout, when compared with the more superficial action of the steam hammer, that the whole mass of an enormous ingot is thoroughly consolidated.

A fair idea of the general arrangement of the above in its larger sizes may be obtained from the view on page 238, of one of 3,000 tons capacity, by Messrs. Henry



FORGING MACHINE.

Berry & Co. In this case the anvil block, main crosshead containing the ram cylinder, the screwed columns, the top crosshead containing two lifting cylinders, and also the overhead girders which support the hydraulic cranes, are



3000 TON FORGING PRESS.

clearly visible. By means of improved valve gear the ram is enabled to deliver blows at a maximum rate of 40 per minute, and as its crosshead is capable of vertical adjustment, forgings of almost any magnitude can be taken in.

Further, the cranes are so arranged as to enable the work to be manipulated with great ease in every direction.

The incidental advantages of the press over the steam hammer for heavy forging are very great. Firstly, the blow does not affect the surrounding buildings nor even the shop in which it is placed, whilst, at the same time, little or no foundation is required, and therefore its position in the works can be altered at slight cost. The press is noiseless and exact in its action, and occupies little space, and although primarily made for *forging* purposes, can be easily employed in stamping, straightening, bending, cutting and punching, the water used in working being otherwise available by means of a simple arrangement of valves and pipes.

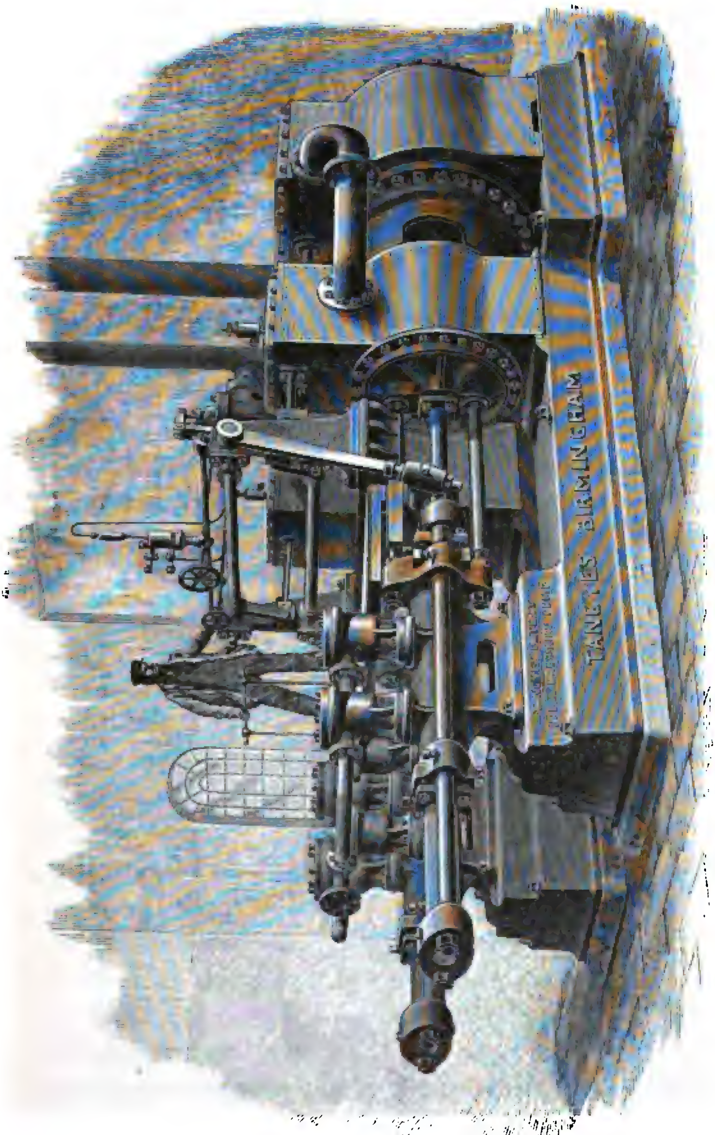
Amongst its numerous advantages may be mentioned the great amount of work that can be done at one heat, thus saving labour and fuel; the employment of *cast iron* dies and stamping blocks, instead of those of steel, as with steam hammers; the superior uniformity in the quality of the material thus produced, and the absence of shocks to the structure which enables it to work a long time without being repaired. Although the working pressures may usually range from 750 to 1500 pounds per square inch, those of 300 to 400 pounds can be conveniently arranged for, recent machines have, however, used pressures up to as much as 4 tons per square inch when the necessities of the case required them.

For a considerable period after Bramah's famous invention, the art of using water power continued in a backward state, as the time occupied in producing great pressures was much too long, and the operation far too expensive and cumbrous for general use. To overcome this difficulty Armstrong invented the *Accumulator*, which immediately opened out a very wide field for the economical application

of greatly intensified and concentrated water power. The beauty of this system lies in the fact that it stores up the energy supplied to it by comparatively small steam machinery, and lets off this power, not only instantaneously, but in an extremely convenient manner, to points perhaps miles distant. Particularly is this the case with regard to the working of gates, cranes, swing bridges, etc, over the whole area of a vast dock estate, the water being conveyed underground by means of pipes, just as it is now being similarly done on a gigantic scale in cities and towns, for the use of the inhabitants.

Nowhere in the realms of engineering does the *Ram pump* occupy so unique and indispensable a position as in this species of work, where its leading features consist of relatively small pumps and valves, and immensely strong parts to enable it to withstand the enormous pressure previously mentioned. There are many sizes and arrangements of these pumps, vertical and horizontal, with single acting and double acting rams, single and compound cylinders, differential arrangements, and so on, to suit the ever varying circumstances of modern practice. In the adjacent Plate we give an example of a powerful set of *Duplex Steam Pumps* of the compound ram-pressure description for steel works, which give a good idea of their arrangement. The high pressure cylinders are each 31″, and low pressure 50″ diameter, rams 6″ diameter, and stroke 18″ for all, the steam pressure being 80 lbs, and the water pressure one ton per square inch. It will be noted that the cylinders are cased with sheet steel, which is more handsome, and more easy to keep clean than mahogany, which soon becomes irremediably dirty.

One of the principles so happily utilised in hydraulic machinery is that when subjected to pressure it transmits



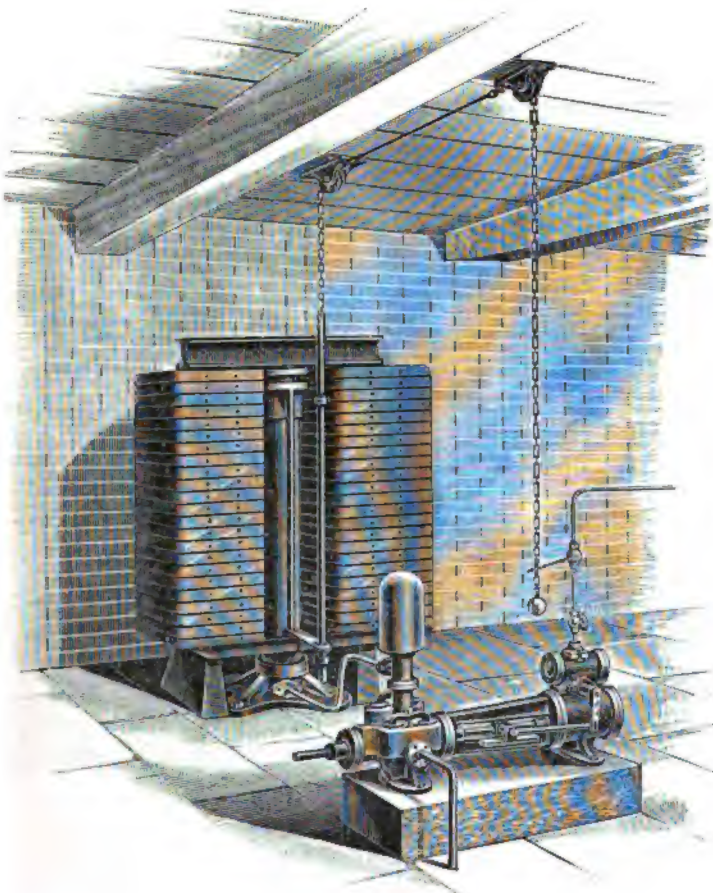
COMPOUND DUPLEX PUMPING ENGINES

it equally in all directions. Hence it follows, that a pressure of say one ton per square inch, applied by a rapidly moving and small pump ram, is at once transmitted to the large and slowly moving ram of the hydraulic press, the water in the pipes being similarly loaded. The fluid power thus produced may be treated as a connecting rod in constant compression, and one, too, that without joint pins or levers, transmits energy in every possible direction, angularly, curvilinearly, and undulatingly, over great distances, with only a trifling loss of efficiency, through pipes whose wear and tear is scarcely anything.

As we said before, the *Accumulator* stores up energy only to let it out when and where required, in the simplest possible manner, just, in fact, as water is supplied to a town from a vast elevated tank into which the fluid is being somewhat intermittently pumped. One of these power store chambers, in a portion of a large warehouse, with its engine, weights, and all attendant gear by Sir W. H. Bailey & Co., is shown in the adjacent engraving.

Here, as in other cases, a vertical hydraulic cylinder contains a ram, underneath which the water is pumped by the engine. To the upper end of the ram a strong cross beam is attached for the purpose of carrying a number of weights sufficient in the aggregate to produce the load which the incoming water has to raise before the required pressure can be obtained. When the engine, therefore, commences its work, the heavily loaded ram begins to rise from its present lowest position, and continues to do so until it reaches its highest point when, by means of automatic gear as shown, the pumps are stopped. In actual practice, however, the ram is constantly rising and falling in accordance with the quantity of water either drawn from its chamber, or supplied to make up loss.

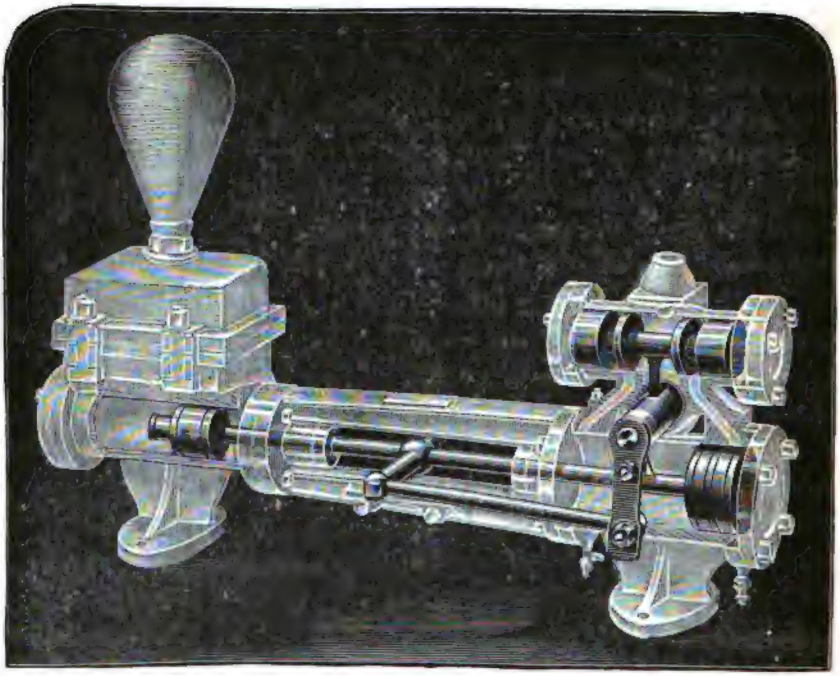
Usually the accumulator is of cylindrical form with the weights annularly placed around the ram cylinder in layers, and cased in by a plate iron covering.



ACCUMULATOR WITH ENGINE ATTACHED.

During recent years pumping machinery has been greatly simplified, as may be noted in the engraving on next page of an apparently X-rayed or semi-de-materialised

pumping engine, which represents a section of that shown in the view of the Accumulator. Here, through their spectral externals, all the interior working parts are visible, and amongst these are the valves, which are worked direct from the piston rod.



POSITIVE ACTION PUMPING ENGINE.

As this pump is for low pressure water, its working barrel is of large size compared with the steam cylinder. On the other hand, the plungers of the pumping engines described on page 240 are proportionately small, simply because the diameter of a ram capable of delivering water at any pressure with a fixed power of engine, has to be

adjusted to suit the fluid load, allowance being made for friction, etc. Hence, theoretically, a piston having 80 square inches area, and 100 lbs. steam pressure per square inch, will just balance a pressure of 1000 lbs. against a ram 8 inches area, or 8000 lbs. against one of 1 inch area, and so on.

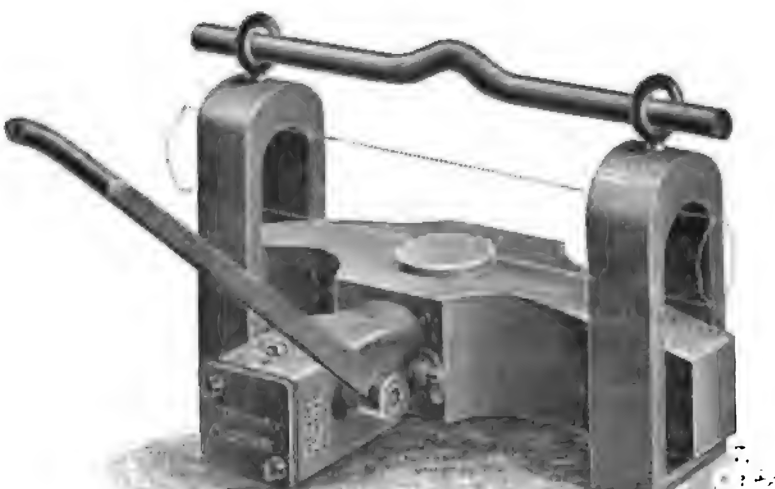
Our Röntgenotyped view is specially instructive in every way, as the beautifully equilibrated piston valves are clearly seen, also the sections of steam and water cylinders, and the method of forming bolt holes, so that by only a little slackening of the nuts the bolts can be disengaged and the cover taken off without any further trouble.

These pumps, variously arranged and proportioned in size, are fitted with simple, compound, and triple expansion engines, for lifts up to as much as 1000 feet, and for hydraulic pressure up to 4 tons per square inch, according to circumstances.

As it frequently happens in various processes that the final portion of a squeeze is the only one in which an ordinary pressure is not sufficient, an *Intensifier* is provided. This simple appliance chiefly consists of a lower ram say 9″ diameter, and an upper one 4½″ diameter, or one fourth of the area of the former. It therefore follows that when the small pump barrel is full of water, and the large one under a pressure of 700 pounds per square inch begins to act upon its plunger, the pressure in the small pump and also the press, etc, connected with it, becomes 2,800 pounds per square inch, or otherwise, according to the relative diameters of the pump plungers.

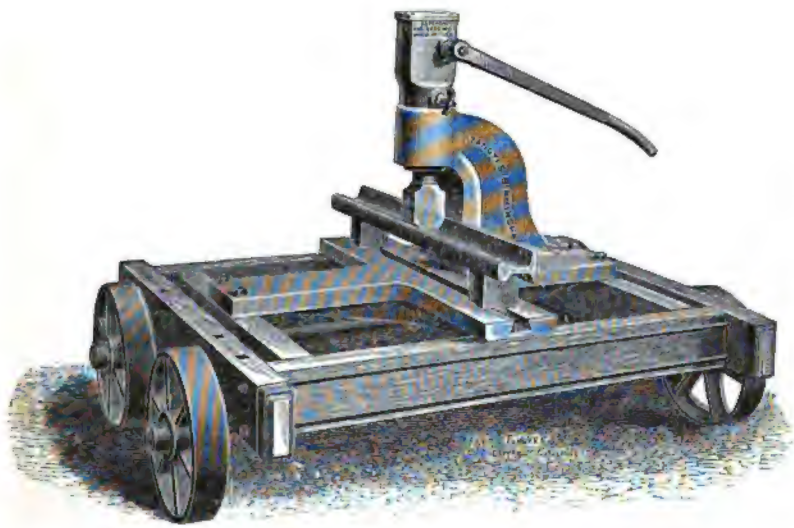
As still further striking examples of hydraulic power in *Portable* appliances such as those used on railway work, we give an illustration of a *Hydraulic Shearing Machine* on

HYDRAULIC SHEARING MACHINE.



HYDRAULIC AXLE STRAIGHTENER.

wheels so constructed that by means of the hand pump an internal ram pressure is generated sufficient to cut from 2½″ to 4″ square or round steel, or 9½″ × ⅝″, to 14″ × 1⅛″ flat bar steel, according to the size of the apparatus, that shown in the view being of the former power. A similarly useful portable appliance for straightening bent shafts or axles up to 5″ diameter in the lathe is also shown, and for straightening rails up to 90 pounds per yard, another



HYDRAULIC RAIL STRAIGHTENER.

arrangement, additionally illustrated, is extremely handy, as it can be made either with plain wheels, or with flanged wheels for running on the line.

Amongst the powerful machinery of this department at Crewe are the *Plate Mills*, the rollers of which are plain turned cylinders, whose vertical distance apart for progressive rolling from the rough to the finished sizes, is regulated by screws as the red hot metal is passed and re-

passed between them until the required thickness is obtained. This for engine outside frames is usually 1"; for boiler plates, etc., $\frac{1}{2}$"; and for tender tanks $\frac{3}{16}$" to $\frac{1}{4}$". After leaving the mill, the plates for engine and boiler construction are sheared to the required dimensions by machines which cut as much at one stroke as others would do in several, as may be seen on reference to the Plate of one of them on page 140.

In this portion of the premises all the scrap cuttings of wrought iron and steel collected throughout the establishment are re-worked, after being thoroughly cleaned by rubbing against each other in revolving cylinders, so that not only is there no waste, but a *better* material is obtained. Here, too, some of the specially designed heavy engine-driven shearing machines are to be found which cut into pieces old rails, tyres, boilers, etc., and also a *Circular Saw* which is capable of cutting through an axle 9" in diameter in about 35 seconds, amidst a shower of fiery particles and noise unparalleled.

It may be noted that in the above Steel and Iron Working Departments, as well as in other portions of the establishment, the metals are heated in gas furnaces, the vapour of which is generated in 51 gas producers, and then led to the former by means of underground-pipes. By this method, the surrounding atmosphere is kept free of smoke.

CHAPTER XV.

RAILWAY PLANT MANUFACTURE ON A GIGANTIC SCALE AT THE CREWE WORKS.

Peculiarities of the Boiler Department—The Music of the Works—Failures of early Steel Boilers—First Steel Locomotive Boiler—Its Effect upon subsequent Practice—Hydraulic Machinery—Boiler Construction and Inspection—The Iron Foundry—Preparation of Patterns—Shrinkage Allowances—How to ensure Sound Castings—Sand Preparing Machines—Preparation of Moulds for Castings—Rapid Machine Moulding for Repetition Work—Improved Cupola for Melting Iron—Blowing Machinery—Special Lifting Gear—Brass Foundry—Peculiarities of Brass—Magnetic Treatment of Waste Cuttings.

IN the course of our rambles through the works, we come to the very extensive *Boiler and Tender Tank Shop*, where we found both of these most important details in every stage of construction or repair. Although this department is necessarily much larger than that at the Atlas establishment, it does not vary materially from it in general arrangement. The main difference, however, lies in the fact that while in the latter only new work is executed, in the former the repairs and manufacture of all the boilers and tanks for the whole of the London and North Western system are constantly progressing. This will at once account for its very spacious dimensions, which enable it to accommodate about 90 boilers and tanks at one time, and employ about 600 men.

As we entered this portion of the premises it became very clear that however much hydraulic riveting machines may be used for boiler shells, etc., there is, nevertheless, a

large amount of work which, for convenience, is still done by hand, so much so, indeed, that we had to silently admire everything and reserve our remarks for a later period.

The *Music of the Works* is peculiar in various ways. We have already referred to the *thump—bang*—SMASH staccato movements of the steam hammers, and the magnificently illuminated fortissimo music of the hot steel saws which profoundly impress one with the idea that, after the outrageous treatment their teeth receive, they must be useless, instead of being still in good order, owing to their excellent temper, and an unseen bath of cold water underneath the framing which keeps the metal cool.

The ring of the sledge-hammer upon the blacksmith's anvil is so beautiful that it has been most effectively reproduced in instrumental performances. The *buzz*-cum-*swish*-cum-WHIRR movements of the wood-working machinery; the pianissimo cadences of well ordered lathes, or the exquisitely smooth action of the cold steel sawing machines; the concord of more or less sweet sounds in the finished machine departments generally, with the hum and soft noises of their multitudinous drums, pulleys, belts, etc., as they perform *their* portion of the programme to absolute perfection, is perhaps the most attractive to many, whilst the mechanism of this portion alone of the works, taken as a whole, cannot fail to deeply interest all who view it. When, however, we enter the boiler shop, our ears are assailed with machinery music, sledge-hammer music, and with a deafening outburst of sound produced by hand riveting, that actually, in time, injures the sense of hearing in the workmen.

By means of a plentiful supply of smith's fires, every detail that requires forging or welding connected with

boilers or tanks, is operated upon most satisfactorily. Here, only the shells of the former are made, the fully ten hundred thousand brass tubes used up in a year for new and old boilers, through which the gases from the furnace transmit their heat to the surrounding water, and also the copper fire box plates, being obtained from outside firms.

At this point, it may be well to state that up to the end of 1872 the numerous attempts that had been made to introduce steel into the manufacture of boilers had proved failures, but at the International Exhibition in Vienna in 1873, a locomotive boiler of this material was sent from the Crewe works. This was a very fine specimen of advanced practice, and since that time immense numbers of locomotive and stationary boilers have been thus made at these works without a single failure having occurred. It may be mentioned, however, that the greatest possible care is taken to obtain trustworthy plates, a piece being cut from each and subjected to the most severe tests of every kind, which are registered for future reference.

In this department is to be found a large and varied collection of machines for punching, shearing, planing, bending, drilling, flanging, riveting, etc., some of which have already been described in the Atlas Works chapters. Although the *drilling* of rivet holes in boiler shells may appear to be quite as necessary at Crewe as at any other establishment where boilers are constructed, they are nevertheless *punched*. This fact alone, after all that has been said and written in favour of drilling for years past, will no doubt be interesting to many, as the employment of an apparently obsolete custom is due chiefly to improvements in the manipulative processes.

The rivet holes in all London and North-Western boilers are punched in a machine which has an automatic

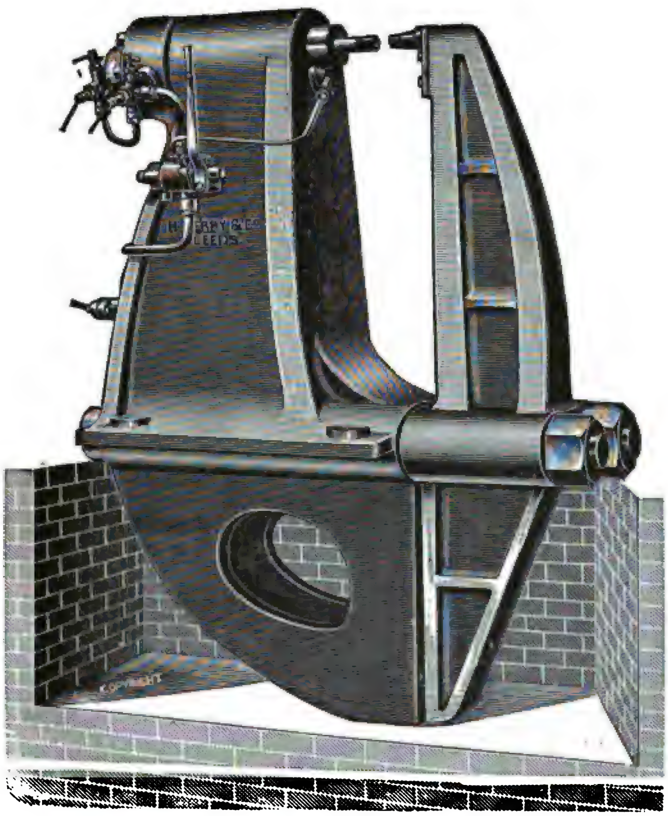
and pitch-adjustable feed arrangement that enables the holes to be perforated precisely the same distance apart throughout. By having the die a little larger than the punch, these holes are made slightly tapered, instead of being parallel, as they are when bored, the two plates to be riveted together being placed with the smallest diameter of the holes next each other, thus ensuring the entire filling of the aperture by the rivet, and preventing any collar from being formed between the plates.

In the circumferential joints, where only two plates lap over each other, the holes are not rhymered, but in the longitudinal joints, where there are three thicknesses of plate, the holes in the middle one are punched a little smaller than the rivet, and afterwards rhymered out parallel.[*] Mr. Webb kindly informs us that the plates at the Crewe Works are made of soft steel, and when punched are annealed, and that after making boiler shells, as described, since 1873, he sees no reason to alter the practice.

So far as the riveting of the plates is concerned, there is perhaps no greater manipulative contrast than is here presented between the two distinct systems of hand labour and machine labour, since, even with the heaviest marine work, silence reigns while the *Hydraulic Riveters* at one squeeze faultlessly perform their part.

The illustration on next page clearly exemplifies an improved variable power 7′ 6″ gap machine of this class, by Messrs. Henry Berry & Co., which is capable of exerting powers of 75, 50 and 25 tons, as required, thus saving at least 50 per cent of water when in operation. The valves are so arranged that they can be adjusted in a few moments to give any of the above pressures on the rivets with the temporarily secured boiler shell segments

vertically suspended in exact position between the dies. These machines are made to different designs up to a gap of 12′ 0″, but for foundation ring, fire-door ring, and other riveting not suited to the above, *Portable Riveters*, similar to

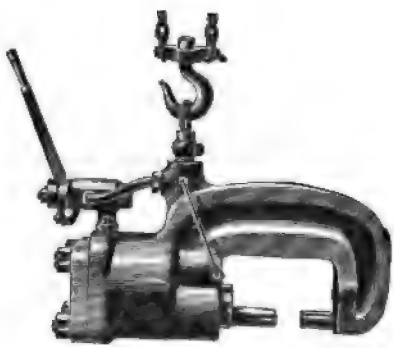


VARIABLE POWER HYDRAULIC RIVETING MACHINE.

that by the same firm shown on page 254, are found very useful, as they can be slung in any position and operated by the hand lever with great ease. They can also be made to swivel in every direction if required.

As one who for a long period has witnessed very many of the changes that have occurred in engineering practice, we cannot but greatly admire the system of hydraulic machinery which was introduced by the late Mr. R. H. Tweddell, and afterwards so successfully developed by himself as to make it capable of world-wide application, especially in cases where no other motive power can be economically employed.

To the non-professional, there is something approaching Arabian Nights' mystery in the ease and silence with



PORTABLE RIVETING MACHINE.

which the most extraordinary performances are accomplished, without any assistance whatever from the wheels, pulleys, bevel and spur gearing, etc., to which, in other machinery, so much importance is generally attached, and which, if suddenly arrested when in motion, may break, whereas the action of hydraulic power under similar circumstances will harmlessly stop.

Is there not something very like Hindoo jugglery in the way in which a gigantic cold or mildly hot steel armour plate is bent as noiselessly as the fall of a leaf, not to men-

tion the snipping of a massive rail or tyre as if it had been so much cheese, or the punching at one stroke of oval apertures 30" by 21" in one inch steel plates—all cold—as if they were mere cardboard?

These apparent mysteries are due firstly to the almost incompressible nature of water, and, secondly, to the ease with which it may be forced under tons of pressure per square inch through small pipes into a large cylinder. Hence it follows that if, for example, a pipe 1⅛" diameter, or one square inch area, discharges water at a two-ton pressure into a cylinder 25½" diameter, or 500 square inches area, we have at once a bending, crushing, or lifting power of 1,000 tons, not only in a wonderfully compact manner, and with an extremely smooth action, but with a safety absolutely unique. This, then, is the secret of the popularity of a power which is now used in endless forms.

When the boilers constructed in the department under review are completed, they are tested with hydraulic pressure to 220 pounds per square inch, and also with steam to 160 pounds, this being the usual working pressure. They, moreover, are periodically inspected for the purpose of noting any defects that may have arisen through ordinary wear and tear, and corrosion, while on service. The employment of hard water having necessitated frequent repairs owing to the deposition of lime on the plates, a chemical process of softening is adopted which has proved very beneficial.

The *Boiler Shell Drilling Machine*, now so popular, has undergone many changes before attaining its present excellence. By the latest improvements, a Multiple arrangement is provided, whose heads and standards are so designed as to enable four holes to be drilled at one time, either for vertical or horizontal riveted joints, in any

direction, or of any pitch, the shell being automatically and truly adjusted in position ready for boring. The table is also fitted with special dividing gear, which produces great accuracy in the pitch of the holes. Further, each head and each drill is capable of independent or united action according to circumstances.

Iron Foundry.

With a sense of relief we passed from the Boiler shop to the large and well-appointed Iron Foundry, to which the former presents a very striking contrast, as the latter may be termed the Abode of Silence. The work of the men employed by day in this department chiefly includes the preparation of moulds for the casting processes of the evening, and is peculiarly characteristic. Firstly, the floor is covered with loose black sand, plentifully strewed with wooden patterns for locomotive and general work. Moulding boxes and foundry appliances of every description also lie about promiscuously. The patterns have been carefully prepared in accordance with the nature and number of the castings to be made from them. Hence, to ensure exactness at every point, and economy in the case of hundreds, or perhaps thousands, of the same detail, metal patterns are used with great advantage.

The preparation of patterns is a special art, since they have to be so constructed that faultless castings can be produced. It is, therefore, necessary to make them a little larger than the intended casting, to allow for the contraction of the metal in cooling, which, although fairly ascertained from practice, nevertheless requires various allowances according to circumstances. Hence $\frac{1}{10}''$ is usually added to every foot in length of patterns for large castings, and $\frac{1}{8}''$, or about 1 per cent. for small ones.

For practical purposes, however, $\frac{1}{8}''$ for cast-iron, and $\frac{1}{6}''$ for steel and gun metal may be taken as sufficient approximations.

Now, how is this one per cent. allowance on every foot and inch of patterns for iron castings to be made with rapidity and accuracy? By the arithmetical process it would be most tedious and often erroneous, but by the use of special rules, or measuring staffs, there is no more difficulty than with the ordinary foot rule, since that of the pattern-maker, though apparently divided into *standard* "eighths," "inches," and "feet," has actually had the one per cent., etc., allowance made already in its dimensions without anyone else suspecting it. When a wooden pattern is made from which an iron one is to be formed, to serve permanently for repetition work, *two* shrinkages have to be allowed for as will be easily seen. A double contraction rule $\frac{1}{4}''$ longer per foot is therefore employed which provides for both of them.

The timber most generally used for patterns is pine, or deal, and mahogany, the two former being the best suited for large ones, and the last-named for small ones, such as spindle valves, toothed wheels, and other delicate work, on account of its closeness of grain and small liability to shrink or twist in drying. To avoid these evils, in any case, the timber should be thoroughly seasoned before being worked upon.

The excellence of a casting primarily depends upon the skill of the drawing office staff, as the pattern maker is guided quite as much by the plans prepared in this department, as the foundry people are by his own productions. One example out of many will be sufficient to prove this. Some years ago a very eminent firm conceived the idea of making "improvements" in the construction of large steam

cylinders, which were of course clearly shown in the drawings. When, however, these cylinders were cast, it was found that some of them were cracked. The plans were therefore altered, and the successes of the past renewed in the future.

Fracture of castings has frequently been caused by improper distribution of metal, and by the introduction of *sharp* corners which ought to have been rounded. Indeed, the latter not only makes a casting unsightly, and robs it of some of its natural strength, but sometimes creates destructive strains in the metal while cooling in the mould, especially with steel, the fluid temperature of which is higher, and contraction greater, than those of cast iron. Other curious phenomena occasionally appear, such as twisting out of truth, the formation of cavities inside the metal, &c., which have to be guarded against at all points by the draughtsman, by the pattern-maker, and lastly by the moulders. Thus it happens that special configuration of details has to be employed when required.

As the *weight* of castings has often to be calculated from drawings, with an amount of trouble corresponding to their design, a simple method is used, when convenient, which gives closely approximate results almost at once, as follows:

Weight of pattern in pine wood when in ordinarily dry condition $\times$ 14 for cast iron, 15 for steel, and 16 for brass.

The best material for receiving impressions from the patterns referred to is sand, as liquid metal has no chemical action upon it; it acts as a good conducting medium for the air expelled from the space filled by the fluid; and lastly, it possesses sufficient adhesiveness when rammed to enable it to retain its form when exposed to the fluid pressure. So important is it, therefore, to have sand of

suitable quality that the site of many foundries have been determined by its presence alone.

The preparation of the sand is most important, since for fine skinned castings a high class material can alone be used. To enable this to be obtained on a large scale with rapidity, a very simple *Vibratory Sand Sifter* is employed, which has proved most useful at Crewe and elsewhere. This consists of an iron tray containing a set of bars for disintegrating the material thrown upon it. Underneath these bars, to which a reciprocating motion is imparted, are placed a coarse and also a fine sieve, through both of which the broken material has to pass until sufficiently refined.

A more comprehensive appliance is the *Moulding Sand Mixing and Preparing Machine*, invented by the foreman moulder of an extensive railway establishment. This machine is capable of thoroughly preparing any kind of moulding or core sand, and combines the three processes of crushing, mixing, and riddling in one operation. The sand is fed into a hopper, attached to the framing, and passes through a pair of rolls which crush it sufficiently. It then passes to rotating beaters which thoroughly mix it to the required consistency and deliver it into a riddle through which the prepared material falls, the lumps which remain being further disintegrated. By the use of the last named machine great economy of labour and better castings are obtained than formerly, one of them alone supplying 80 to 100 light and heavy moulders with sand ready for the foundry.

All kinds of moulds for heavy castings are prepared by hand, more or less elaborately, some indeed requiring large pits in the floor, and the expenditure of much time and labour before being ready for the liquid metal. The great

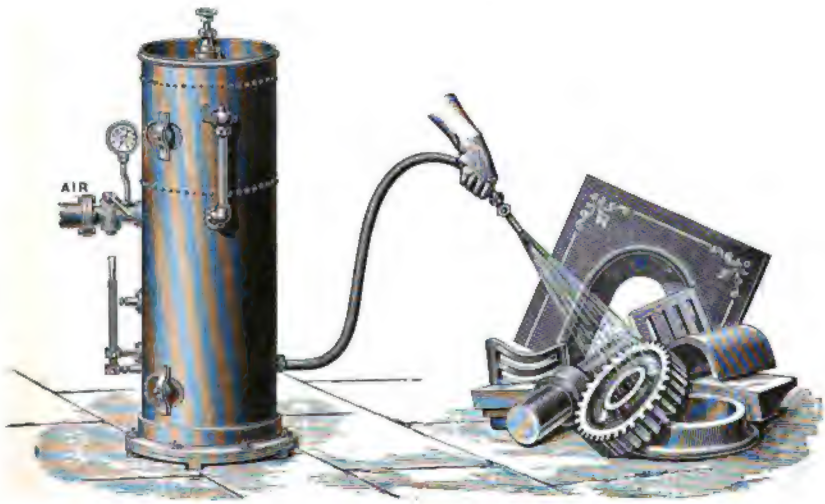
majority of small and medium sized ones, however, are made in the usual moulding boxes, with which every foundry is more or less liberally supplied. A rectangular bar, for instance, can be made anywhere by simply pressing the pattern edgeways into the sand and then pouring in the metal. When, however, we come to cylindrical and other castings of extremely varied shape, say, for example, an eccentric, or a valve box, other methods must be used which will enable a perfect impression to be taken of *both* sides of the pattern.

This is accomplished by having two boxes filled with well rammed sand, one of which contains on its face an impression of the lower half of the pattern, and the other the upper portion of the same. When these moulds have been carefully finished they are secured in position face to face in such a manner as to produce complete castings when the metal has been poured in and allowed to cool.

In places where an enormous quantity of repetition work of moderate size is made, some more rapid method than that of moulding by hand was found necessary. Hence, Mr. F. G. Leeder, foundry manager at the magnificent new works of the Singer Sewing Machine Company, so successfully designed a machine that would turn out a *complete mould at one operation*, that no less than 42 of them are now employed in the above establishment, besides being highly valued accessories in very many others. Some idea of the usefulness of this invention may be gathered from the fact that in these works, where 6,000 hands are employed, upwards of 1,000 complete moulds have been made at a small machine in one day by the aid of three boys, and from 400 to 600 larger ones in the same time by means of unskilled workmen. In railway works the above process is extensively employed in the production

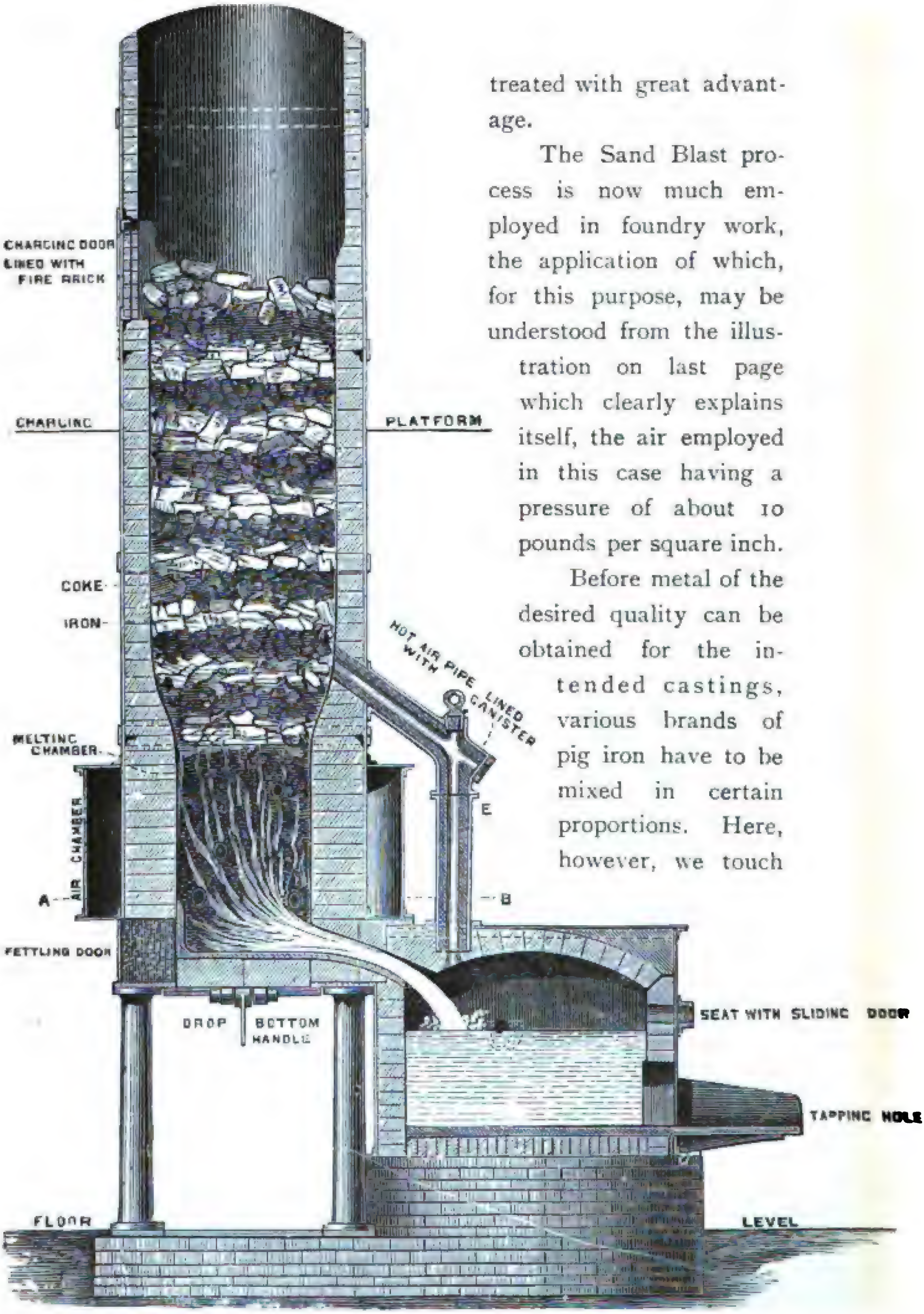
of immense quantities of slide valves, brake blocks, fire bars, etc., thus saving much time.

Formerly, it was the custom to clean castings by hand after having all their rags and tags chipped and filed off. This process is still in use, but at Crewe the *Tilghman Sand Blast*, or "Liquid Grindstone" system, is employed with excellent results. It may be described as a method of cutting, boring, grinding, dressing, pulverising, and



SAND BLAST IN OPERATION.

engraving stone, metal, glass, wood, and other hard or solid substances, by means of a stream of sand or other suitable material forcibly driven against them by steam or by compressed air. By its aid the hardest steel, etc., irregular surfaces, and recesses almost inaccessible, can be easily operated upon. Hence it comes to pass that worn out files may be re-sharpened in a few moments as they stand, instead of being softened, ground, re-cut by hand, and re-hardened, immense quantities of these being thus



treated with great advantage.

The Sand Blast process is now much employed in foundry work, the application of which, for this purpose, may be understood from the illustration on last page which clearly explains itself, the air employed in this case having a pressure of about 10 pounds per square inch.

Before metal of the desired quality can be obtained for the intended castings, various brands of pig iron have to be mixed in certain proportions. Here, however, we touch

the secret arts of the founder, to which no reference need be made. When the mixture has been decided upon, the next thing to be done is to melt it in a *Cupola*, such for instance as that of the improved arrangement by Messrs. Thwaites Brothers, illustrated opposite.

This apparatus consists of two portions, namely, the cupola proper or the furnace in which the iron is melted, and the receiver in which the melted metal collects, the latter being generally made of such dimensions as to enable it to hold the production of half an hour's fusion. The application of the receiver produces economy in fuel, while the special disposition of the tuyeres on the shell of the cupola promotes a rapid combustion of coke and fusion of the iron, as all the air from the blowing engines is thus beneficially employed. Various appliances are also used for controlling and directing the distribution of air to the best advantage, and in addition to these, the adoption of a drop bottom not only makes the work of cleaning out the cupola less laborious, but gives facilities for entering it for repairs to the lining.

The cupola is made in sizes capable of producing from one to eight tons of metal per hour, the total height from the ground being from 20 to 28 feet. At the level marked "charging platform," the pig, or scrap iron, coke, etc., are delivered through the "charging door" into the interior of the cupola, where, under the influence of a strong blast of air, the metal is soon reduced to the liquid state. The pure fluid falls to the bottom and is then drawn off when required for casting purposes, the impurities rising to the surface being skimmed from time to time. To facilitate these operations as much as possible, a steam or hydraulic hoist is employed for lifting the materials to the platform, the rest of the work being accomplished by manual labour.

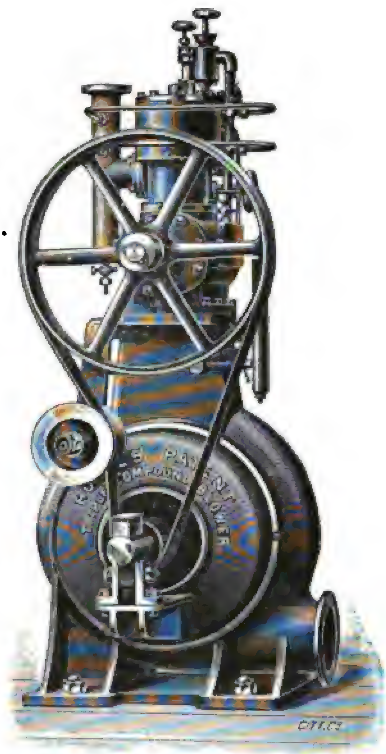
The *Blast* apparatus for supplying the cupola with air is on the well-known principle invented by Mr. Root, the motive power being derived from a specially designed and directly connected Duplex engine. These blowers are variously made, a very popular form for small and intermittent work being of the hand-driven type for portable smiths' hearths, etc., from which they range in size up to those having a delivery of 19,000 cubic feet per minute.

One of the latest improvements in this class of machinery is that of Messrs. Hodges & Co., illustrated in the opposite view. Here, the blower is of a compound nature, the engine being placed above it to economise space as much as possible. The dimensions of these are made to suit a delivery of from 80 to 12,500 cubic feet of air per minute, at pressures usually ranging from 4 to 20 ounces per square inch. The amount of metal melted per hour is from 15 cwt. to 25 tons. Diameter of outlet $2\frac{5}{8}''$ to $23''$, and number of smiths' fires supplied with air 1 to 140, the speed of the fans varying from 600 to 5,000 revolutions per minute.

For heavy lifting work in a Foundry, overhead cranes are most useful, as also are the ordinary jib cranes for intermediate purposes which are too well known to need comment. We therefore have all the more pleasure in noting a new arrangement which has been fitted to the foundries of various railway and other establishments.

This crane is beautifully simple in design and in operation, the horizontal jib being of rolled joist section, and so pivoted to an inverted hydraulic lifting cylinder that its rise and fall of six feet upon the fixed ram can be easily accomplished either at a very rapid speed, or at one so slow as to be hardly perceptible. The jib will slew, and the load-suspending carriage travel in or out with the

slightest hand pressure, which is a great advantage. The usefulness of these cranes may be gathered from the fact that they can be attached at suitable intervals either to the stanchions of a building or along the walls, and are ex-



COMPOUND BLOWER.

tremely handy in drawing patterns and closing boxes, or in performing any light work for which the heavy cranes are unnecessary.

Brass Foundry.

Brass has been a most useful metal from the time of the

Brazen Serpent to the present. Coming down the stream of time we find the same material holding a very exalted position, being used in large quantities for the most important works, such, for instance, as enormous city and temple gates, and statues of all sizes, including the Colossus of Rhodes, which was 70 cubits in height. Hence we may conclude that the *Brass Founder's* art was, at an early age, in a very advanced state.

The alloys which, in combination, form the above substance, are chiefly copper, zinc, and tin, the skilful proportioning of which produces a material suited for a variety of purposes, and of greater or less tenacity, according to circumstances. The Bronze alloys are also variously mixed, so mixed sometimes, as to produce a metal that, while capable of being forged or rolled, may have a tensile strength of at least 35 tons per square inch. Hence its admirable adaptability to engine and other work, where great strength combined with non-corrosive powers are required.

One of the best examples of this is to be found in the screw propellers of large steamers, which may bend without breaking even under the most severe and irregular treatment, while on the other hand, the immense strength of the metal enables light, thin, and sharp edged blades to be used, thus producing diminished friction.

Although the Brass Foundry is of comparatively small dimensions, it nevertheless occupies an indispensable place in the works, as many minor details, such as bearings, valves, and light fittings generally, must necessarily be made of this expensive metal. There is not much to be said in connection with this department, as previous remarks upon pattern making, moulding, etc., are here quite applicable. It may be mentioned, however, that as the

melting points of wrought iron and steel are about 3,250° Fahr., cast iron 2,200°, and copper 1,950°, that of yellow brass is 1,834°, thus enabling simple crucibles to be employed containing about 120 pounds of metal, which is melted in furnaces placed below the level of the floor, and lifted out with ease when ready for use.

Besides the ingots of fresh metal, a large quantity of waste cuttings from the machine and other shops are here used up. As many of these scraps are collected from the various floors, they must necessarily be extensively mixed with refuse iron and steel, and to enable the brass and copper to be separated from them they are thrown into a large box containing a revolving spindle having magnets spirally attached to it. These attract the baser metals to them, only to be swept away by revolving brushes, thus leaving the more valuable scraps to be easily gathered for remelting purposes.

CHAPTER XVI.

WOOD-WORKING MACHINERY AT THE CREWE WORKS.

Wonders of Modern Timber Working—The Manual System—Carpentry and Joinery Operations—Saw Mill and its Arrangement—Practical Notes—Log Sawing—Powers of the Modern Band Saw—Novel Type of Band Saw—Special Combination Circular Sawing Machines — Planing and Moulding Operations — Construction of Cutter Blocks—Mortising and Tenoning on a large scale—Mechanical Sand Papering Process—Emery Wheel Grinding of Tools—Latest Practice in Tool Cutting Velocities.

We now come to the *Wood-working* regions of the Crewe establishment, where, on a very large scale, carpentry, joinery, and timber cutting of all descriptions are actively carried on. The whole territory, indeed, forms a scene that to some, no doubt, is fascinatingly attractive, owing to the wondrous manner in which timber is manipulated from first to last. Under the guidance of one man at one machine, for example, a rough log is rapidly sawn, planed, drilled, adzed, and finally turned into a finished and interchangeable buffer beam as one stands looking at it, and so on throughout the whole series of operations connected with other details. Here, however, let us pause and reflect upon this extremely useful branch of practice. To describe it properly would require volumes, but a few graphic touches may nevertheless be introduced that will help the reader to obtain a general idea of the main processes which are indicated by the term *Wood-working* in its world-wide significance.

To enable us to gather the desired information as completely as possible, we paid special visits to the famous and

extensive establishments of Messrs. Robinson & Son, at Rochdale, and Messrs. Ransome & Co., in London, so that what we had noted at Crewe, Earlestown, and elsewhere, from a *user's* point of view, might be embellished by a few additional remarks from the constructor's standpoint. Here, however, we must retrace our steps.

The earliest timber construction on a gigantic scale was the Ark, but *how* it was built, and with what kind of tools, we are unable to say. All we do know is, however, that the time occupied in building indicated the extremely primitive nature of the manipulative processes. The next great event in the history of carpentry was the erection of Solomon's Temple, which was founded in the year 1012 B.C., and as it was finished only seven years later, we must look behind the scenes for the cause of such rapidity in execution. The ancient records, therefore, inform us that on this occasion Solomon wrote to Hiram, King of Tyre, somewhat as follows:—

"As I desire to build my house as quickly as possible, please let me have some of your skilled woodcutters to help my own people on Mount Lebanon, and I shall pay you whatever you require."

So pleased was Hiram with this letter that he sent 30,000 hands, and thus the total working staff in the celebrated forest amounted to about 70,000 labourers and 3,600 "overseers," which will at once account for the unusual speed with which the magnificent edifice was erected.

During the present century, immense improvements have been made in all departments of wood-working machinery; indeed, so extensively have these been utilised during recent years as to be almost beyond belief. From the primitive axe and adze workmanship of the carpenters

of 200 years ago, to the refined and perfect machines of the present, has been a gigantic stride; but Watt's steam engine gave, within a very limited period, an impetus to everything of a mechanical nature that has no parallel in the history of the world. The ease and simplicity with which tree-felling, log-sawing, heavy band sawing, and circular sawing machines can now be used, not upon single trees only, but upon *whole forests*, will show how the manual style of the past has become obsolete, except in places where nothing better can be had. When, too, it is remembered that timber is required in countless forms and on a most extensive scale at home and abroad, it will be noted that for initial process operations these machines are invaluable, as they prepare the way for the carpenter and joiner, whose labours in connection with every kind of building are indispensable.

The former receives his material from the sawyer in beams, planks, etc., which he cuts and combines, sometimes most skilfully, for constructive purposes, such as gigantic trestle bridges, roofs, timber houses, and so on. The scientific design of these, however, comes within the province of the engineer, whose knowledge of the strength of materials, and also of the machining operations, enables him so to proportion and arrange his details as to obtain the greatest strength at the least cost.

Broadly speaking, the carpenter has for his colleagues the mason, bricklayer, and ironworker, whereas the joiner assimilates himself with the rough furnisher of interiors. Since not only in railway works, but in shipyards and elsewhere, there are many varieties of wood in constant use, including fir, pine, oak, teak, etc., for constructive purposes, and those of a more valuable character for internal embellishments, it naturally follows that this in

itself complicates a subject the ramifications of which are intricate and widespread. This is owing to the fact that a machine, when perfectly designed, is made to suit the kind of timber it will most generally operate upon, which may be very soft, as with fir, or very hard, as with oak and other woods. To enable this subject to be put as clearly as possible, the two firms we have mentioned have kindly supplied a list of machines made by them for the Crewe, Wolverton, and Earlestown works of the London and North-Western Company, some of which we shall illustrate as we proceed.

Let us suppose that we have entered the *Timber Working Department* at Crewe, that portion of it, in the first place, which includes the *Saw Mill* and *Joiner's Shop*. The first thing that strikes one somewhat forcibly is the absence of the overhead shafting and belting usually to be found elsewhere. Here, however, all the motive power gear is placed *below* the floor, where much is to be found in rapid and beautifully smooth motion, engines of 90-horse power and large pulleys and driving belts being used to bring the shafting up to its required velocity. The great advantage of having the shafting, etc., thus situated, is due to the very high speed which is necessary for various purposes throughout the shop. It is therefore advisable either to drive the main shaft with great rapidity, or to introduce a number of intermediate shafts for the same object. The disadvantages of having so many counter-shafts with their pulleys and belts overhead are great, and as a heavy main shaft in that position would throw an undue strain upon the building, it is considered better to place it below the floor, and to fix its plummer blocks to piers detached from the walls of the mill.

The engines and boilers should as a rule be placed

in a separate building, thus giving greater security from fire, and preventing the former from being exposed to the dust and grit so continually flying about. As, however, all the shavings, waste cuttings, etc., are used up for firing purposes, it follows that not only are the shop floors kept clean, but considerable economy results from the very extended use of waste timber instead of coal.

To enable the machines to turn out good work with the greatest rapidity, their cutters are made of the very best steel, the edges having the most approved formation, and their velocity the highest that can be obtained. With this in view, the bearings of shafts and spindles running at 4,000 or 5,000 revolutions per minute are made about four diameters in length, the lubrication being of the most perfect character, and the whole machine so designed, balanced in its working parts, and fixed to the foundation as to be incapable of vibration. There are other points that require careful attention regarding the arrangement of the buildings, sizes and capabilities of various machines, etc., and when these have been properly worked out in detail, a wood-cutting establishment is in condition for executing the most elaborate as well as the most simple work with a speed unparalleled in the mechanical processes.

As the *Saw Mill* produces food for all the other departments, it deserves the first attention. It is here that the enormous logs from the forests of America, Canada, Scandinavia, India, etc., are initally machined by means of vertical frame or other saws which cut them into beams, planks, etc. These are very carefully stocked in the *Drying Shed* until in proper condition for being further operated upon.

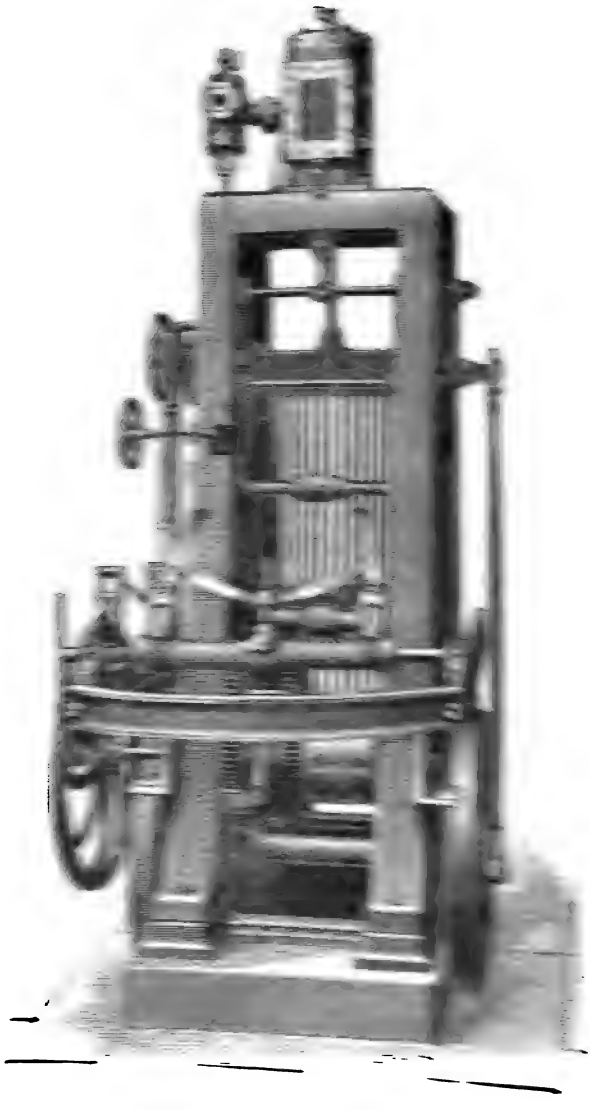
An excellent example of an overhead engine-driven *Self Contained Timber Frame*, by Messrs. Robinson & Son, is

shown on the next page. This is a type of machine suitable for erection in almost any locality, with very little depth of foundation. As the engine is directly coupled to the crank shaft, and all the working parts are in sight and easily accessible for cleaning, lubricating, etc., it cannot easily get out of repair. The sizes of the logs to be operated upon range from 16″ to 48″ square, by 30′ 0″ long, and in every case the strength of the machine is made to suit the maximum strain when working. This depends upon the hardness of the wood, the number of saws in action at one time, and also the amount of feed motion given to the log by means of the fluted rollers upon which it rests. The number of saws in use at one time, and also their spacing, depend entirely upon the required thickness of the timber when cut.

For the sake of clearly exhibiting all the details the mill floor and its connections have been excluded, the travelling carriage, too, has been shortened in for convenient illustration. Numerous varieties and sizes of this class of machine are made, including those which are either side or top engine-driven, belt-driven, &c., all of which have proved very useful, and in some of which as many as sixty saws have been simultaneously employed.

Many will no doubt remember the *Band Saw* of early days, which was only suitable for ornamental carving, it is therefore surprising to find such an enormous expansion of the uses to which it can now be applied. Who would have thought, thirty years ago, of employing this saw for cutting through massive blocks of iron and steel, as well as heavy timber? And yet such has been the march of progress that all these operations are of continual occurrence in many of the large establishments.

With a desire to still further extend its sphere of action,



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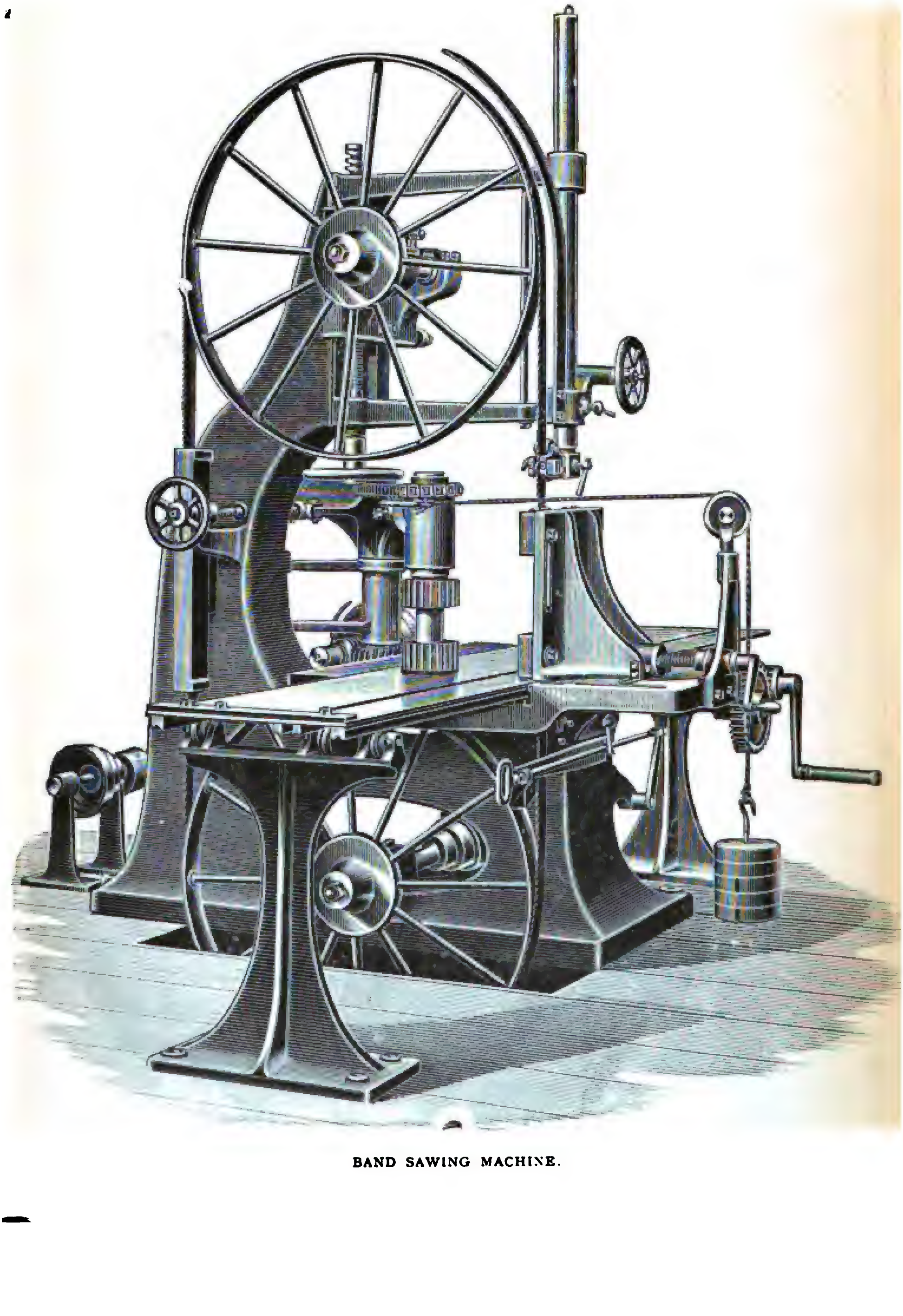
numerous firms have designed a great variety of special, and in some cases enormous, machines of this type, for rough log squaring and other purposes. As an example of the manner in which the Band Saw is appreciated in Canada, we may mention that at Messrs. Booth's immense saw mills on the banks of the River Ottawa, saws 52 feet long and $\frac{1}{16}$ inch thick are employed. By their aid the daily production of the establishment has amounted to 1,000,000 feet of timber, cut from 7,000 logs. These logs were first floated down from the forests to the required spot, then dragged by an endless chain into the mill, and after being operated upon were again launched into the stream to pursue their voyage to the end.

A good illustration of the above class of machines, by Messrs. Robinson, for log, deal, and ordinary sawing, is shown on page 276. This may appear somewhat complicated owing to the variety of purposes for which it is employed, but the feed apparatus can be removed from the table when it is desired to produce curves and other work by the hand-feeding process. When stripped of the above accessories, and the table slightly modified, a good idea will be formed of an extremely simple arrangement frequently used for mere carpentry and joinery purposes.

This simplicity is maintained in various forms, down to that of the Fret Saw of the cabinet maker and carver, both of whose operations it indispensably aids. The machine owes its excellence to the thin, narrow, and flexible strip of exquisitely tempered steel that forms the saw, which differs from all others, as it has to be united at the ends to enable it to pass continuously over pulleys without breaking at the joint. This was primarily the main obstacle, until M. Pèrin, of Paris, discovered a method of faultlessly brazing the two ends, and thus successfully overcoming the



BAND SAWING MACHINE.

difficulty. For cutting logs up to 5′ 0″ square, or 6′ 0″ diameter, it is more useful than either the large circular saw, or the vertical frame previously described, as the waste is much less, and at the same time a smoother cut is produced.

One of the greatest novelties in wood working appliances of the present day is the *Landis' Patent new Horizontal Log Band Sawing Machine*, manufactured by Messrs. A. Ransome & Co., which possesses so many striking advantages and points of constructive interest that it is necessary to describe it more fully than usual.

This machine, illustrated opposite next page, is capable of converting round or square logs of any kind of timber up to 48″ diameter and 28′ 0″ in length, whilst effecting a considerable saving in timber as well as in motive power. The cost of labour in operating is extraordinarily small either when the machine is used for breaking down, opening, log squaring, or board cutting purposes, the excellence of the work being greatly due to accurate finish of the working parts; to the absolute balance of the saw pulleys; to the rigid fixing of the log upon a perfectly true metal travelling carriage, and to various other causes.

The weight of the machine is about 11 tons, and its foundation up to the ground level is of concrete. The saw blade which is 38′ 0″ in length, and has a velocity of about 7000 feet per minute, is carried on a pair of specially constructed wrought steel pulleys 5′ 0″ diameter by 6″ in width. No india rubber or other substance is used on their faces, the saw running on the metal rims with its teeth sufficiently projecting.

The saw pulleys are fitted on steel shafts running in very long self-lubricating swivel bearings, and are also fitted with adjusting gear for altering the distance between them to suit saws of different lengths, and to give the

requisite tension to the blades. The same hand wheel which produces this strain serves also, in combination with a simple mechanism, for canting the pulleys, so that the saw may be enabled to run in the desired position upon them, and as the latter works perfectly cool even at the highest rates of feed, no spring or weight adjustment is required for compensating the expansion or contraction of the metal.

One of the most strikingly original features of this machine are the screwed columns which are made to rotate by self acting gear for the purpose of varying the height of the saw, the position of which is indicated by an index pointer attached to the saw carriage passing over a vertical graduated brass scale fixed in front of the operator. After each cut, the saw is lowered to suit the required thickness of the next plank, the movement being regulated to a nicety by means of another pointer which works round the outer edge of a graduated disc, the locking of the saw carriage at the desired height being automatically effected.

The travelling table is constructed of wrought steel longitudinal and transverse girders, the former of which may be of any desired length. The upper surface of the table is fitted with a series of adjustable dog cramps worked by screws from either side of the carriage, the cramps falling low enough to allow a board only ⅛" thick to be left after the last cut.

The feed ranges from 4 to 80 feet per minute, and is driven by a variable friction gear which is so completely under the control of the operator that the rate of advance of the log can be instantly changed from the slowest to the fastest, or any intermediate speed as required. The backward motion of 400 feet per minute, is also worked by friction gear, and is so manipulated by the sawyer that the

carriage can be instantaneously started, reversed or stopped altogether.

The operator shown in the engraving has the entire control of the machine within his grasp. At his left is the hand wheel with its indicating disc by means of which the thickness of the plank is regulated, while at his right hand are four levers for the following purposes:—No. 1 starts and stops the saw; No. 2 starts, stops, and reverses the timber carriage; No. 3 works the self acting rising motion of the saw; and No. 4 varies the rate of advance of the log.

The sizes of the machine chiefly in use are those for logs up to 48″, 60″, and 72″ diameter respectively, no sawing machine hitherto employed being capable of suitably dealing with such heavy timber. Some idea of the extremely rapid operation of this machine may be formed from the fact that it will cut from 60 to 80 superficial feet of boards in hard wood per minute, while in soft wood the production is nearly twice that quantity. As compared with the other types of machines for log sawing it is proved in practice that one of the Landis' Saws will do as much work as four vertical Log Frames, and more than ten times as much as the Horizontal board cutting machines.

The following is the result of three hours' regular work of the Band Saw, including the necessary stoppages for changing saws and putting on logs. The Machine was worked by one man, while two labourers removed the sawn boards as they were cut, and assisted in fixing fresh logs on the carriage. Every board produced was straight, flat, and of even thickness throughout, the surface being practically smooth. Besides this, the power required to drive the saw was considerably less, *in proportion to the amount of work it turned out*, than that required for any other description of log-sawing machine.

	Superficial feet of Sawing.
AN ELM LOG, averaging 33″ diameter by 14′ 4″ long, cut into 27 one-inch boards and two slabs in 40 minutes	899
A WHITE WOOD LOG, 28¼″ square, 16′ 5″ long, cut into 51 half-inch boards in one hour ...	1,989
A MAHOGANY LOG, 15″ square by 20′ 7½″ long, cut into 19 boards of various thicknesses...	492
A WAINSCOT LOG, 12″ by 18″ by 13′ 7″ long, cut into 17 one-inch boards...	232
A KAURI PINE LOG, 18″ square by 15′ 2″ long. Six half-inch boards only were cut from this log	137
Total production in three hours in superficial feet	3,749

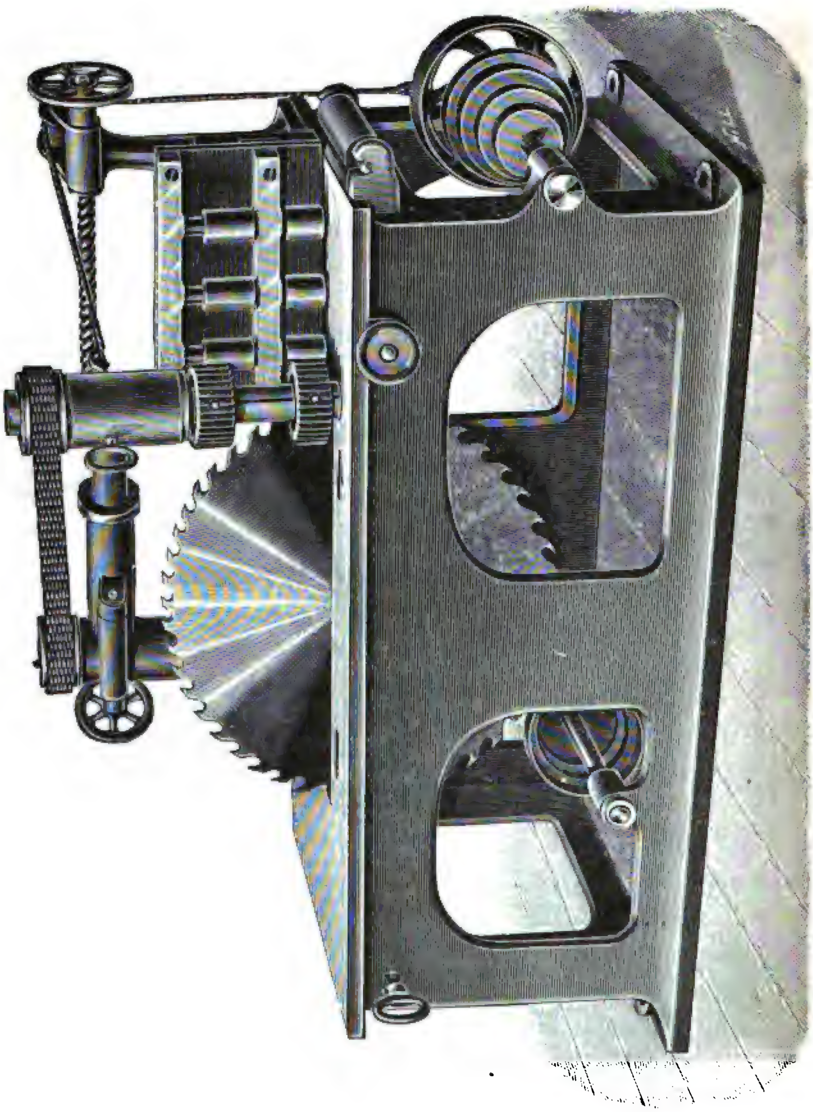
The indicated H.P. actually required when sawing a log of Java Teak 16″ square into half-inch boards, with various rates of feed, is given in the following table:—

No. of Trial.	Nature of Work.	Width of Log.	Feed in feet per minute.	Superficial area per min. in feet.	Remarks.	I.H.P., including Engine.	I.H.P., used by Band Saw.
1	Engine & Shafting	—	—	—	All belts on loose pullies	15·5	—
2	Ditto, Saw running	—	—	—	Not cutting	23·8	8·3
3	Cutting Java Teak	16″	11¼	15	True cutting	37·4	21·9
4	Ditto	16″	20	26⅔	Ditto	41·4	25·9
5	Ditto	16″	27¾	37	Ditto	43·3	27·8
6	Ditto	16″	36	48	Ditto	51·9	36·4
7	Ditto	16″	51	68	Ditto	58·3	42·8
8	Ditto	16″	51	68	Ditto	59·0	43·5

In the above trials, the saw employed was 4" wide and No. 18 W.G. slack. From these it will be seen that when cutting Java Teak, with a production of 68 superficial feet of sawing per minute, which is nearly its full capacity, the machine required 43½ net indicated H.P. to drive it, and as modern engines usually indicate about three times their nominal power, Messrs. Ransome advise an engine of 20 nominal H.P. for driving one Band Saw with its saw-sharpening machine. When, however, it is used for forest operations, where the timber is recently felled, and the saw can be driven direct from the fly-wheel of a Portable or any other Engine, both the saw and the sharpening machine may be easily worked by an engine of 16 nominal horse power.

The best known of all the sawing machines is the "Circular," of which there are many varieties, large, as well as small. Although very simple it is nevertheless capable of numerous valuable combinations for the purpose of planing, moulding, tenoning, mortising, boring, etc., to suit the views of purchasers.

One of the Crewe machines with radial arm and roller feed, by Messrs. Robinson, is shown in the Plate on next page. This is considered the most useful type of self feeders, as it can be used for both deep and flat cutting, and as the feed motion is continuous, a large quantity of work is executed. The column on which the radial arm swings is fixed at the back of the table in such a position that the front is left unobstructed, which, in many cases, is of great importance. If the machine is required to act with hand feed for intermittent work, or with rope feed when sawing round logs, the radial arm can be swung entirely out of the way. As the artist has strikingly depicted the *teeth* of the saw in the lower portion of the framing, their



RADIAL ARM ROLLER FEED CIRCULAR SAWING MACHINE.

nature will be clearly seen, and as a saw 3′ 6″ diameter makes 1,000 revolutions per minute, it is necessary to use the utmost caution when manipulating such a dangerous instrument.

The varieties of the Circular Sawing Machine include, besides the above, those with long travelling tables for tree cutting—pendulum cross cutters for joiners, etc.—compound machines of various kinds—those with gear feed, rope feed, and hand feed—those of the multiple self-acting cross cut description for shaping pavement blocks by the hundred thousand; and so on, to suit the ever-varying circumstances of advanced modern practice.

The action of all the above primary machines is clearly apparent from the Plates, when, however, we come to those of the *generally useful* class for planing, moulding, etc, which may be difficult to understand, a few remarks on this point become necessary. Let us therefore follow the beams, scantlings, and planks, so liberally provided by the sawyers, through the succeeding operations which either transform them into constructive, or into ornamental details with marvellous celerity.

Amongst the appliances required for this may be mentioned the *Planing and Moulding machines*, whose leading principles may be here described for the benefit of general readers.

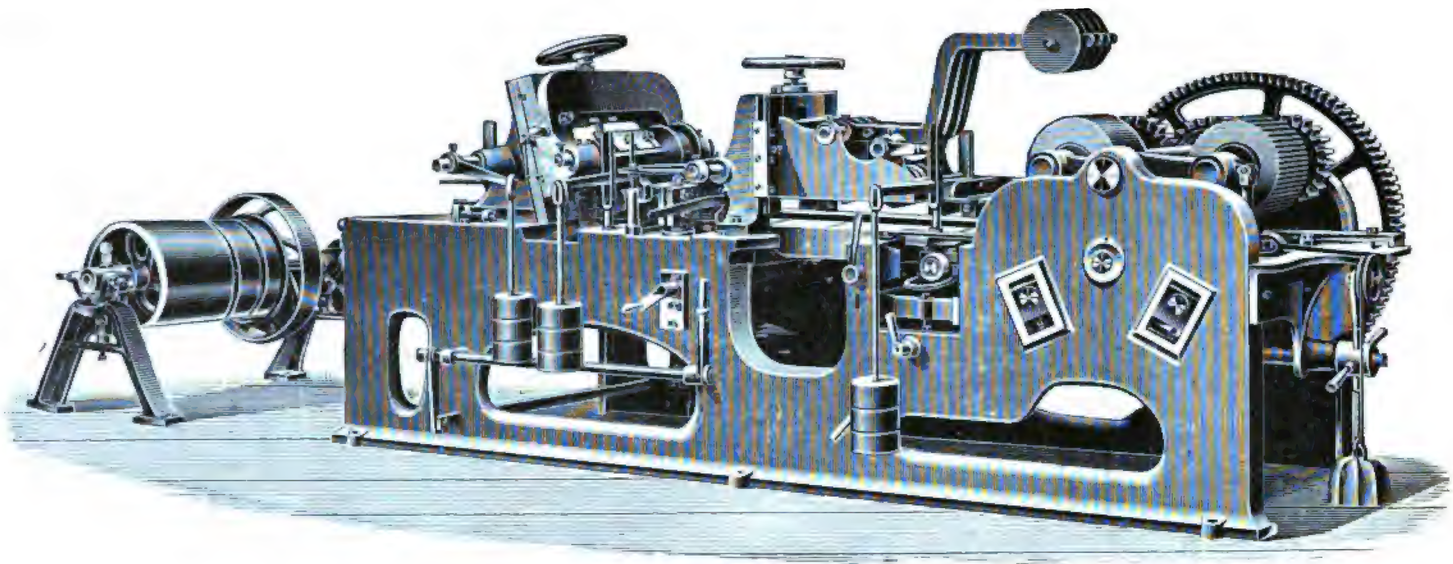
Suppose then, that we have before us a fir plank 11″ × 2″. Let us also imagine that two swiftly revolving horizontal spindles carrying blocks armed with straight cutters, are so placed that the plank, if passed between them, would be just smoothed up. If, now, two vertical cutter blocks are placed at the sides so that the timber will be similarly treated on its edges, we shall have an arrangement which at one traverse of the plank finishes in flat and

smooth style the whole of its sides and edges. If, however, one or more of these cutters is shaped so as to produce curved, bevelled, or channelled outlines on the sides or edges, or all together, we then have a combination which, in the most efficient manner, and at one time, performs every operation automatically and with exact interchangeability.

As in all other machines, the greatest care is bestowed upon the construction and fixing of the cutters, upon which the excellence of the work entirely depends. These are of infinite variety, the specially shaped blocks to which they are attached being either forged or fitted on steel spindles, their sides being also grooved, or otherwise made to receive the bolts that fix the cutters.

One of the above *Combined Planing and Moulding Machines*, by Messrs. Robinson, shown in the adjacent Plate, is an appliance of great usefulness for various purposes. It is fitted with four cutter blocks, so as to work all the sides of the wood at the same time, thus enabling them to cut single or double mouldings of any pattern, or to plane, groove, and perform various other operations if required, as we have rudimentarily explained by the previous remarks. The feed motion is derived from fluted rollers which carry the material forward at a rate which varies from about 15 to 50 feet per minute, according to the peculiarities of the wood or the nature of the work. The above machine is made to suit timber having the maximum dimensions of 9″ by 3″ and 12″ by 5″.

In many timber constructions tenon and mortise joints are indispensable on account of their excellent binding properties. In the bush of Australia and other wildernesses they are still cut with the hand-saw and chisel, here, however, something better must be employed, and therefore



COMBINED PLANING AND MOULDING MACHINE

several varieties of the well-known *Tenoning Machine* are in use for general work, capable of forming either single or double tenons up to 20″ by 8″, with precision and rapidity.

To enable these operations to be performed, the timber is cramped to a table, which runs easily by hand on friction rollers. When thus secured, the end is passed between two swiftly revolving cutter blocks with end shoulder scribing discs, which are capable of vertical motion to suit the thickness of the tenon. If this is required to be *double*, the cutter spindles remain stationary, so that a wriggling saw may work between them driven by independent gear.

It will no doubt be fully apparent that tenons cannot be of any use without having apertures to receive them. This being so, these mortises must be excavated by hand if suitable machinery is not available. The manual process can be accomplished by boring holes in the timber and then chiselling out the rectangular aperture, as with engine details in the past. To avoid this evil, however, a variety of machines are now fitted with boring and chiselling tools capable of passing through timber of any dimensions up to 12″ square, the maximum breadth of chisel being 2½″. After the first hole has been bored equal to the width of the opening, the chisel is brought into play until the mortise is completed.

The stroke of the tool is instantaneously varied, or stopped altogether, by means of a centrally jointed connecting rod which is under the control of a treadle, thus saving the time that would otherwise be occupied in starting and stopping by belt gear. The table is fitted with longitudinal, transverse, and vertical slides, which, by the hand gear, are workable in every direction.

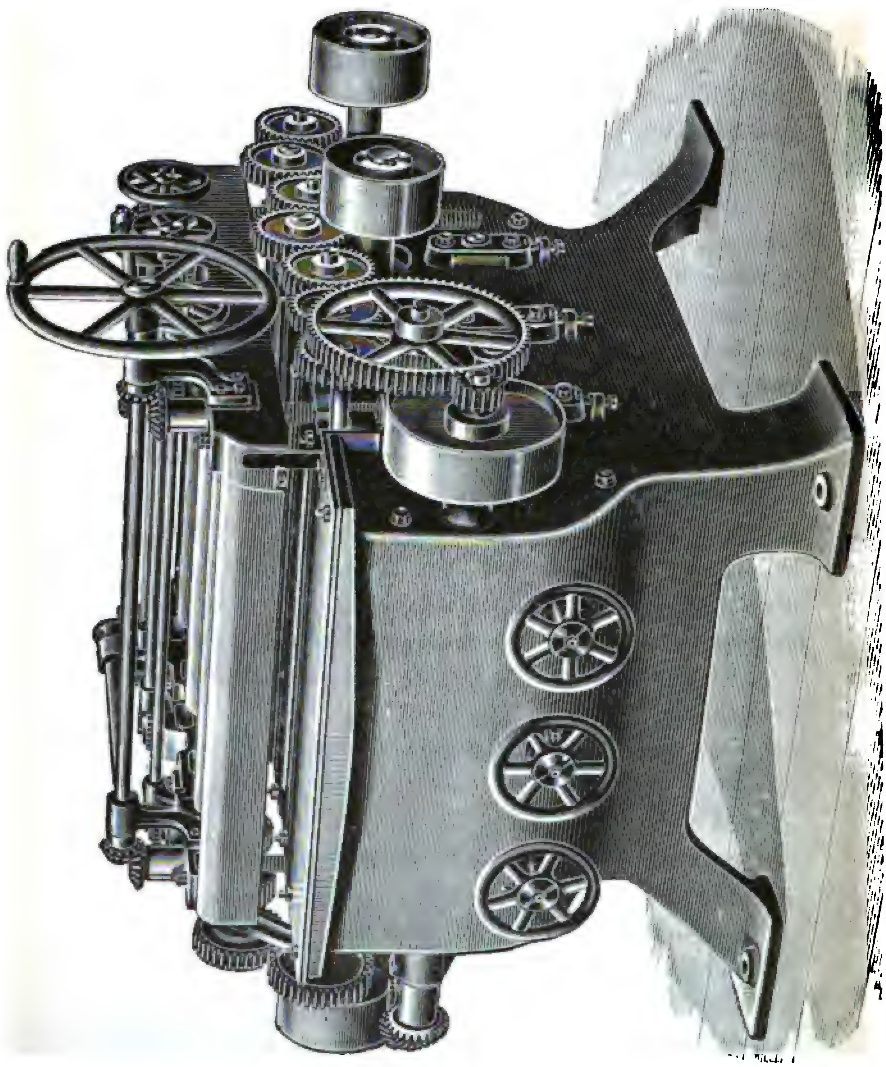
For slot, as well as for complete mortising in either

hard or soft wood, horizontal machines are provided with a sawing, grooving, tongueing, and rebating arrangement, which is intended for all kinds of jobbing work. Here the mortising operation is performed by means of suitable boring bits, the timber being clamped to a table, the hand lever of which regulates to a nicety the length of mortise and feed motion at the same time.

Everyone, probably, is acquainted with the old manual sand papering process that was so inherently defective. An American engineer noting this invented a machine, which, through the amendments of Messrs. Robinson and Son has at last attained a very high degree of excellence, and proved a valuable labour saver.

The *Invincible Three Cylinder Sand Papering Machine*, adjacently shown, to which we refer, has its cylinders so covered with sand-paper of various grades, and so made to slightly oscillate, as to produce with great rapidity work of the highest polish, each cylinder being adjustable either in motion or at rest. The paper is fastened to the revolving cylinder in the simplest manner, and with great rapidity; and to prevent any clogging of the surfaces through accumulated dust and grit, an exhaust fan is supplied to carry the latter away. The machine is made in five sizes, capable of operating upon timber from 24" by 4", to 60" by 4", and with this in view, the great usefulness of these machines in establishments where polished work is produced in immense quantities will be fully apparent.

In these few remarks upon *Wood-working Machinery*, we have only referred to some of the principal appliances of this nature at Crewe, Earlestown, and Wolverton. It may be well to note, however, that as the efficiency of all these machines very greatly depends upon the perfection of their cutting tools, it is absolutely necessary to have the



THREE CYLINDER SAND PAPERING MACHINE

best means of accurately dressing and sharpening them when worn.

For short cutters, an ordinary grindstone, with *Emery Disc* attached for fine edge finishing, does well, but for moulding cutters of all kinds a *Multiple Grinding Machine* becomes indispensable. For long and straight-planing cutters, however, *Self-acting Emery Grinding Machines* are necessary.

A very useful Crewe appliance for dressing vertical, horizontal, and circular saws, is a *Saw-sharpening Machine*, in which the two first named are held by a vice whilst the emery disc does all that is required, circular saws being fixed on a vertically adjustable spindle to suit various diameters.

As proper *tool-cutting velocities* are of immense importance, it may here be said that, according to the latest practice, *Circular Saws* should, as a general rule, be run at a circumferential speed of 9,000 to 10,000 feet per minute.

Band Saws should travel at the rate of about 5,000 feet for ordinary work, but in specially constructed machines this may be advantageously increased to 7,000 feet.

Rotary Cutters for planing and moulding should similarly have a speed of 5,000 to 7,000 feet at their edges, and *Emery Discs* a circumferential velocity of 4,000 to 6,000 feet per minute. With these data in view, it is not difficult to ascertain the speed of spindles and shafts, and also the wheel and pulley gearing necessary to produce such results, which, indeed, form the basis of all calculations for machinery of every possible description, either for wood or for iron-working.

CHAPTER XVII.

MAIN CONSTRUCTIVE DEPARTMENTS AT THE CREWE WORKS.

Millwrights' Shop and its varied Work—Chain Making and Testing Shop—Weldless Link Chains—Smithy and its Contents—The Electric Welding Machine—Immense Locomotive Building and Repairing Departments—Diversified Dilapidations—Paint Shop—Distinguishing Marks of Locomotives—Wheel Shop—Rapid Axle Machining Processes—Special Axle Box Planers—Gap Lathes—Systematic Taper Turning—Table of Lathe Speeds—Peculiar applications of the Lathe—Spring Shop—Spring Buckle Removing Machine—Hydraulic Test Process—Signal Fitting Operations—Improved Details—The Signalling of the Lines.

LEAVING the timber-cutting departments of Crewe behind us, let us now proceed to the other spheres of interest and activity which are so abundantly to be found in this unique establishment. In the *Millwrights' Shop*, which comes next in order, we find a great variety of work in progress. This includes stationary engines, warehouse appliances, light and heavy lifting gear, electrical, hydraulic, and all other kinds of machines for general purposes throughout the whole of the railway system, which are either in course of construction or undergoing repair. It may be observed that, while in the purely locomotive departments there must necessarily be a great amount of repetition employment, here there is sufficient variety to deeply interest ambitious students of engineering, and enable them to understand more clearly the inner secrets of all-round railway practice. The constructive machinery, however, hardly requires comment, as it is of well-known types.

We next enter the *Chain Making and Testing Shop*,

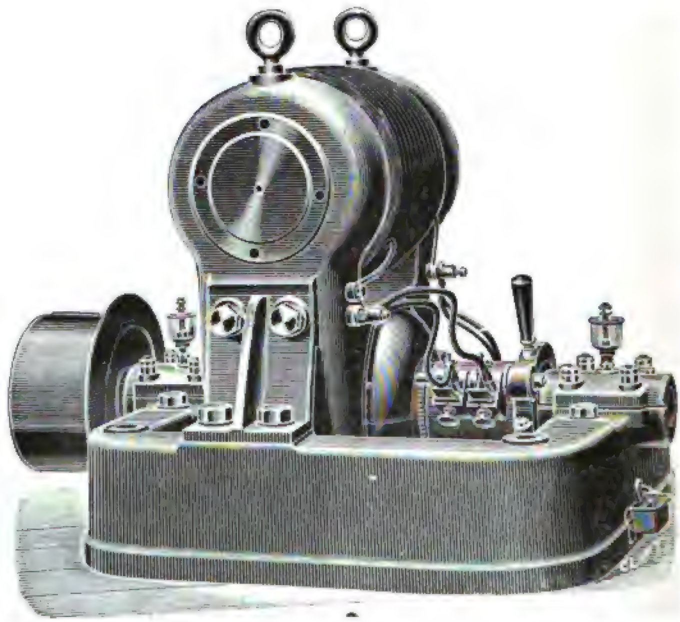
where every description of chain is made, and where samples of steel from boiler plates, etc., and other materials are subjected to the most severe treatment to prevent even the possibility of future accidents through hidden flaws or imperfect manufacture. It may be taken as an axiom that all structures are no stronger than their *weakest* part, no matter how much the material may be piled on elsewhere. Hence, when the part of *least* strength is experimentally known, practically scientific proportioning of all the other parts is readily attainable. By one of the most recent inventions in chain making, weldless links can now be made by machinery, which for many purposes have proved very èconomical.

Upon passing into what is known as the "Old Works" territory, we enter at once upon a grand field of observation, this portion of the premises being entirely devoted to the repair and manufacture of locomotives. As, however, we have gone into the latter branch of the subject in the Atlas Works chapters, nothing more need be said.

Passing onwards, we reach the *Smithy*, with its 120 blower-blasted hearths, where all the smaller parts of the engines, etc., are forged large enough to allow for their machining to the exact dimensions. This, indeed, is a centre of life and energy, in which numerous steam hammers are constantly employed. As each fire is worked by a smith and his attendant hammer man, it may readily be supposed that the ringing of the anvils under repeated blows, and the sparks which fly around, have a very fine and picturesque effect, which to visitors is best viewed at a safe distance. Welds in this shop are either made under the steam or the sledge hammer, an *Electric Welding Machine*, however, is additionally employed, by means of which pieces of metal are united by fusion, the required heat

being generated at the points of contact by an electric current. Hence, welds that cannot otherwise be produced without a disconnection of parts, may thus be rapidly and perfectly formed.

The manner in which this process is carried out may be gathered from the adjacent view of a Dynamo by Messrs. Scott & Mountain for these purposes upon the "Bernardos," or arc principle.



ELECTRIC WELDING MACHINE.

The positive pole of the dynamo is connected by cables to the article to be welded, the negative pole being attached to a carbon holder, which is held in the hand. On making contact with the carbon, and then withdrawing it to a suitable distance, an arc is established, and the surface of the metal containing the defect rapidly heated.

Small pieces of steel are dropped into the faulty part, and these quickly melt and fill it up. The same process may be applied to the welding of boiler flues, tubes, and irregularly shaped articles, for which complete plants are supplied when required.

Leaving the *Erecting Shop* out of sight, for reasons previously given, we find ourselves in the vast *Repairing Shop*, 993′ 0″ in length, by 106′ 0″ in breadth, where at least 300 engines may be operated upon at one time. The scene is impressive, owing to the extremely varied states of disorder of so many locomotives, fully 2,000 being here repaired annually, and so titivated and touched up at every point as to look eventually quite new after all the wear and tear of their past lives. Here may be found at one time the representatives of 14 different classes of locomotives, from those of the magnificent Compound, to the commonest shunter, one of the former, now before us, being in a state of demi-semi-wreck, through serious derailment. Others, again, are in a state of chaos, with boilers gone, with framings dishevelled, with wheels missing, and with the general working gear more or less disarranged.

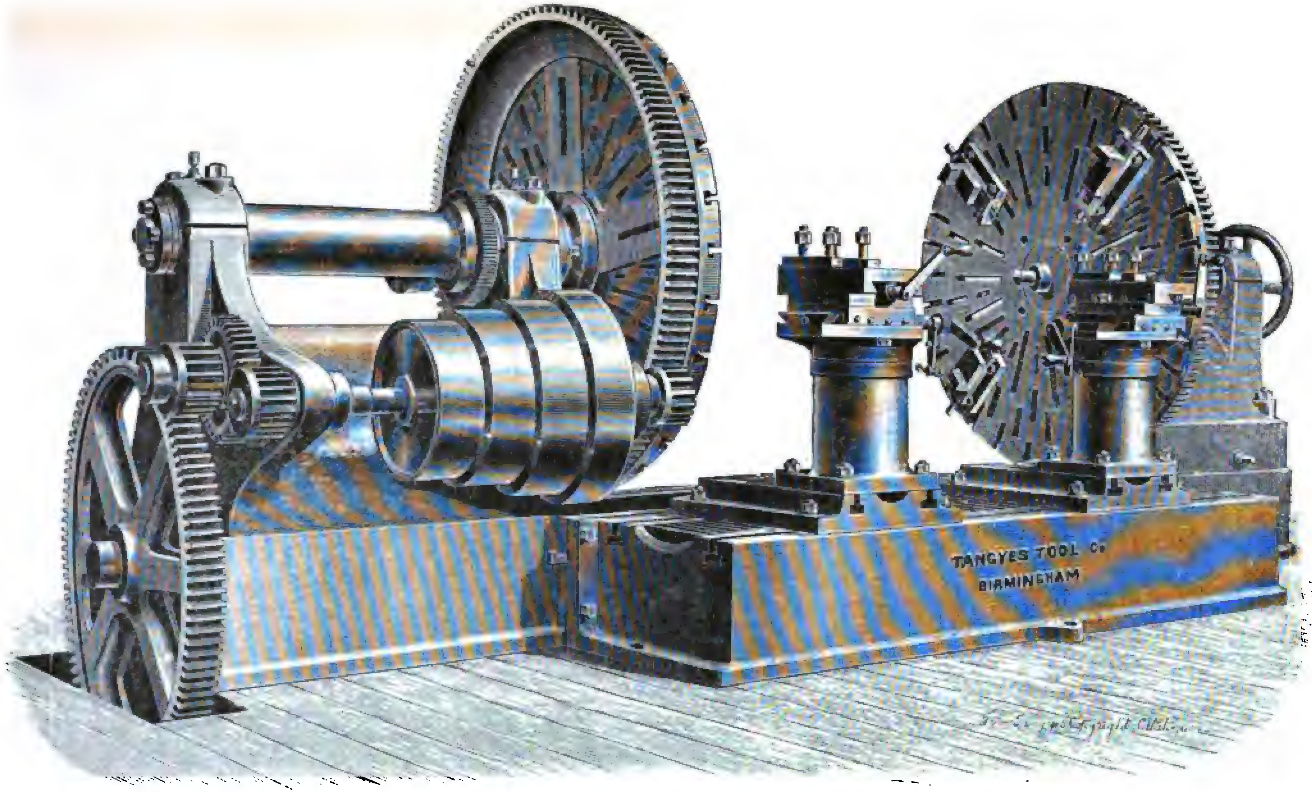
The whole place looks like a vast mechanical hospital, where dislocated, distorted, broken, bent, and twisted members are lying upon the floor around us in a state of greasy dirt, ready to be sent, after cleaning, to the machine and fitting shops for rectification and renewal. The shop itself is a splendid specimen of ingenious design, as all necessary labour-saving machines and appliances are at hand. Overhead cranes are also sufficiently numerous to sweep the whole area, and carry engines bodily through the air to any desired spot.

When the repairs have been effected, the engines are taken to the *Paint Shop*, where, after the application of

the required number of coats of paint and varnish, and superfine polishing, they are ready to reappear in public, and continue their arduous labours. As a steamship owner employs a certain colour of funnel to enable his vessels to be recognised at a distance, so also do railway Companies adopt special foundation colours for their locomotives, which may be green, or blue, or reddish brown as on the Midland, or any others, singly or in combination, as distinguishing marks. For this reason the London and North Western prefer *black*, which, with a little relief touching up, and fine varnish, gives a better and more substantial appearance to a mechanical structure than one would suppose, and is preferable to light blue or emerald green, which are not suitable for machinery.

Dark blue or green seem to be good serviceable colours, but that of the Midland locomotives has not only a warm appearance, but harmonises well with the polished parts, which in some engines are so fully visible. In this respect, however, distinguishing features have more influence than mere aesthetics.

As the repairing and new erecting departments are extensively supplied with much of their heavy gear by the *Wheel Shop*, let us now take a turn through this part of the premises, whose name indicates the nature of the operations chiefly conducted in it. This soon becomes apparent as numerous *Wheel Lathes* rise to view, and also an extensive assemblage of wheels from say, 7′ 6″ drivers, down to 3′ 6″ leaders and trailers, etc., that have either been turned or are waiting to be operated upon. The usual plan is to have rows of the above lathes down one or both sides of the shop, axle lathes and other heavy machines being placed where most convenient. To aid all these most efficiently, a line of rails traverses the centre of the build-



SIX FEET DIAMETER WHEEL LATHE.

ing, so that wheels may be run in and then lifted by an overhead crane, or by jib cranes, to any of the machines. The Plate on page 295 gives a good idea of the general appearance of this class of machine, which holds a most important position at Crewe, and in many other places.

For quick running purposes the cone pulley shaft has a pinion gearing direct into the large face-plate wheel, but at the other end it has another pinion which transmits motion to the spur wheel whose shaft runs through the bed. These latter produce, in conjunction with the cone speeds, a great variety of motions either to both face-plates at the same time, or to each of them separately, the headstock to which the right-hand one is attached being capable of longitudinal traverse. The gripping jaws on the above are indispensable for tyre boring or other similar work, and the slot bolt holes equally so for general purposes. The slide rest supports can be easily moved into any position, and to make the feeds suit these changes, they are automatically actuated by a small overhead vibrating shaft with levers and chains worked by the fine pitched spur wheel on the main spindle, which actuates an eccentric with its gear placed behind.

The machines referred to are usually designed for operating upon engine wheels from 3′ 6″ to 8′ 0″ diameter, that illustrated being of the 6′ 0″ size. For the turning, etc., of wagon and carriage wheels, about 3′ 3″ diameter, in immense numbers, special and comparatively inexpensive lathes of a similar class are very usefully employed.

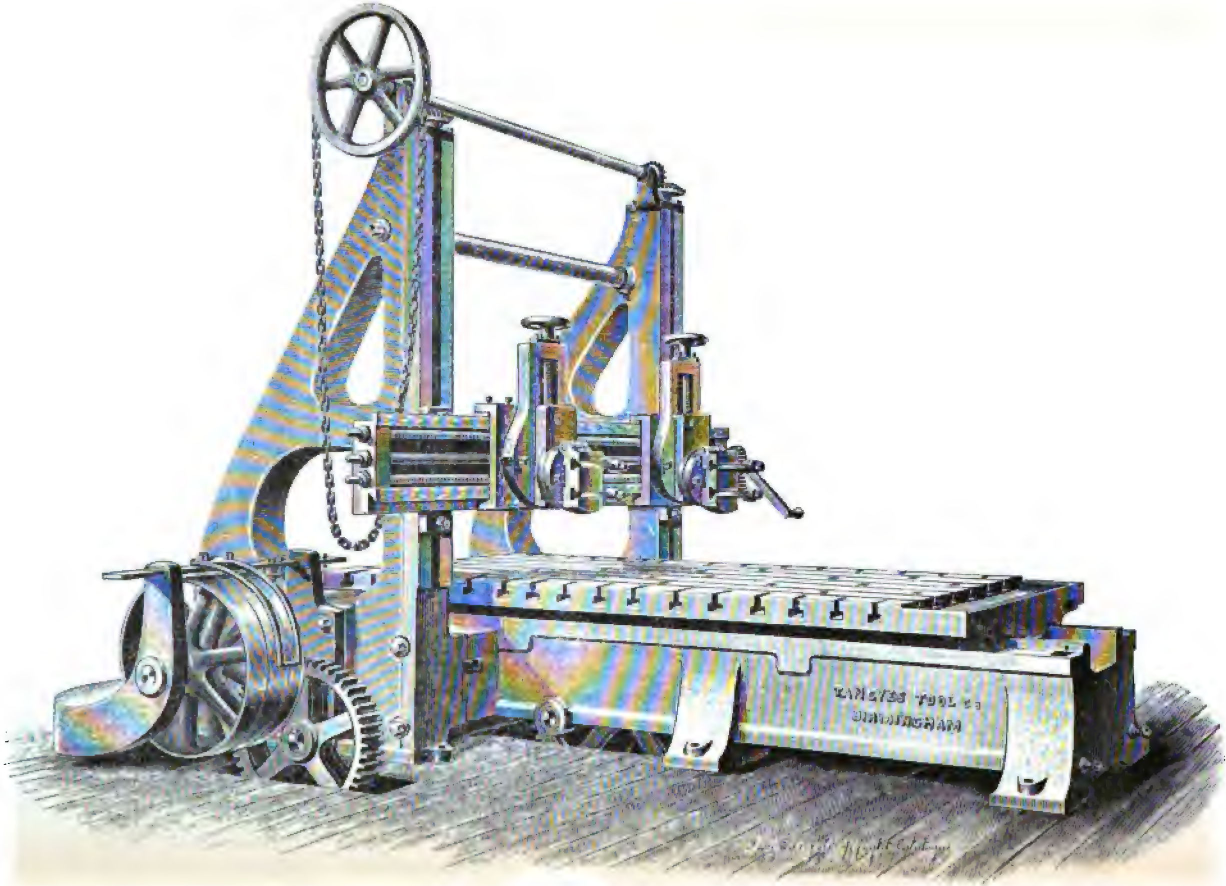
The *Crank Axle Lathes* at Crewe are specially designed for dealing economically and accurately with the heaviest class of work. At the front of each of these machines there are three saddles and slide rests for sliding purposes, and at the back there are two saddles, each having two slide rests

for cutting the outsides of the webs of the cranks, the whole of the seven tools being available at one time. After a powerful nibbling machine has roughed the pins out of the solid metal, the lathe finishes them by the aid of temporary suspension brackets, fixed truly in position at the ends of the axle. The ends of the cranks are semi-circularly formed in a special planing machine, the tool bar of which has the required radial motion automatically imparted to it.

By means of another special planing machine, whose cutting tool is radially fed, the U shaped insides of a number of axle boxes are finished at one setting, whole rows of them having their exterior surfaces trued up in an ordinary *Planing Machine* somewhat similar to one shown in the illustration on next page. This machine will plane a width of 54″ by 12′ 0″ in length, and may be fitted with three or four tool boxes if required. It may also be considered a good representive of a class which, in various forms and sizes, is now very generally employed.

It may be noted that if work of any kind has to be *angularly* surfaced on its top side, this can easily be done by wedging up one end on the table to the required position. As it happens, however, that at Crewe enormous quantities of rail switches and crossing points have to be thus treated, some more rapid and exact method must be used. Hence, we find that for this purpose ordinary planers are fitted with double tables—one over the other—the upper of which is hinged at the back end, and made capable of angular adjustment at the other end, thus ensuring complete interchangeability with the least amount of trouble, while at the same time a number of rails placed side by side may be simultaneously operated upon.

By this arrangement, existing machines may be easily



LANING MACHINE.

altered. Recently, however, a very simple *Duplex Planing Machine* has been employed, having two slide beds, on each of which a tool carriage travels. These slides are so attached to their foundations as to allow of any horizontal angular movement that may be required, the rail being fixed between the carriages, and planed by both tools at once with great precision.

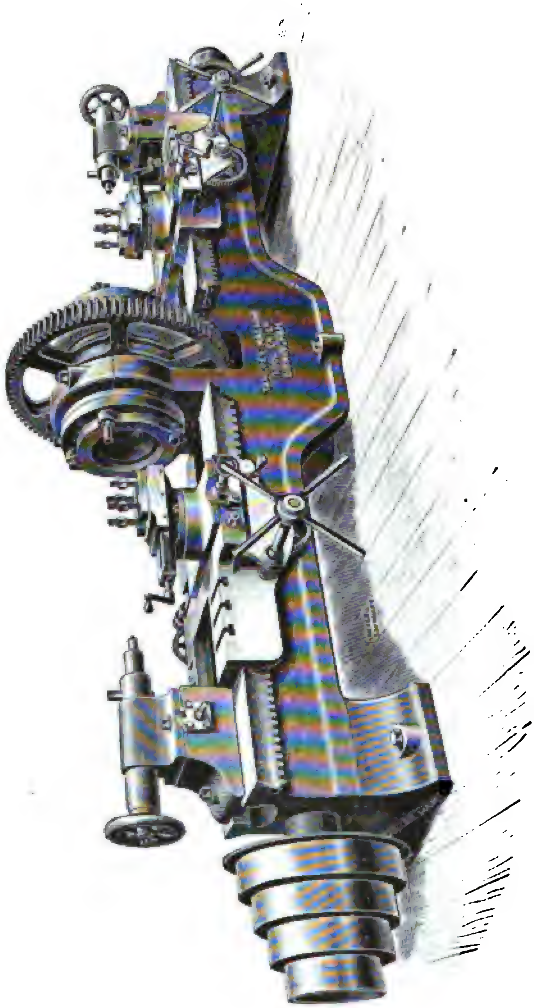
As in railway work generally, enormous quantities of straight axles are used for engines, tenders, carriages, and wagons, the *Double Axle Lathe* was invented so that each end of the above could be turned at one time. The Plate on next page of one of these improved machines, by Messrs. Tangye, shows very clearly their general arrangement, the fast headstock not only containing in itself the driving power, but when fitted with face-plates and centres which can be bolted to its hollow spindle, may be used for ordinary turning, and also for facing purposes.

The saddles are right and left hand, the slide rests having indexed swivels for taper turning, and as one of the loose headstocks is capable of transverse motion, axles can be easily put in or taken out of this machine, whose height of centres is 14″, and the lengths admitted between them 10′ 0″ in one piece, or 3′ 6″ in two pieces.

As the Crewe establishment executes large quantities of general work, it necessarily requires more or less powerful ordinary lathes to carry on the various operations, we therefore show in the Plate on page 301, a *Sliding, Surfacing, and Screw Cutting Gap Lathe*, which will help to indicate the arrangement of others as a class.

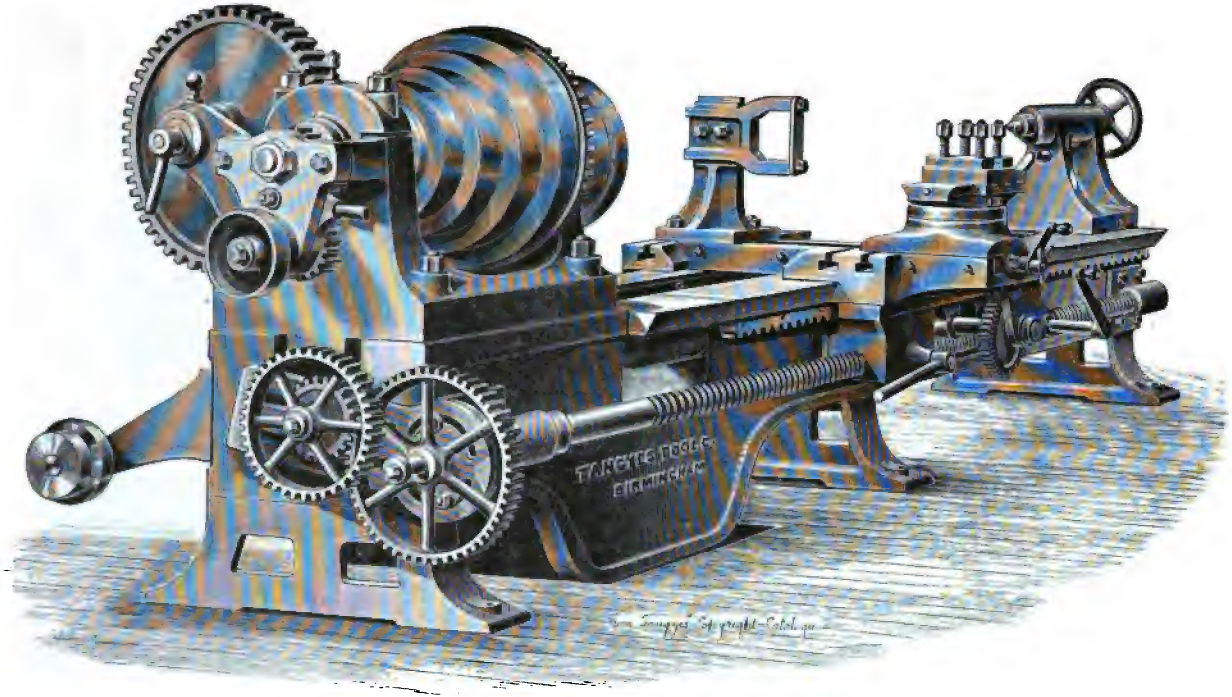
This machine has 18″ centres, a bed 21 feet in length, and is fitted with a guide screw for screw cutting, a rack for quick hand traverse, and a shaft at the back worked by a pair of cone pulleys which produce four different rates of

feed for sliding and surfacing purposes. Although in other machines duplex, and even double duplex compound slide



14" CENTRE DOUBLE AXLE LATHE.

rests are employed, one only in this case, is considered necessary. To prevent long and small shafts or rods from

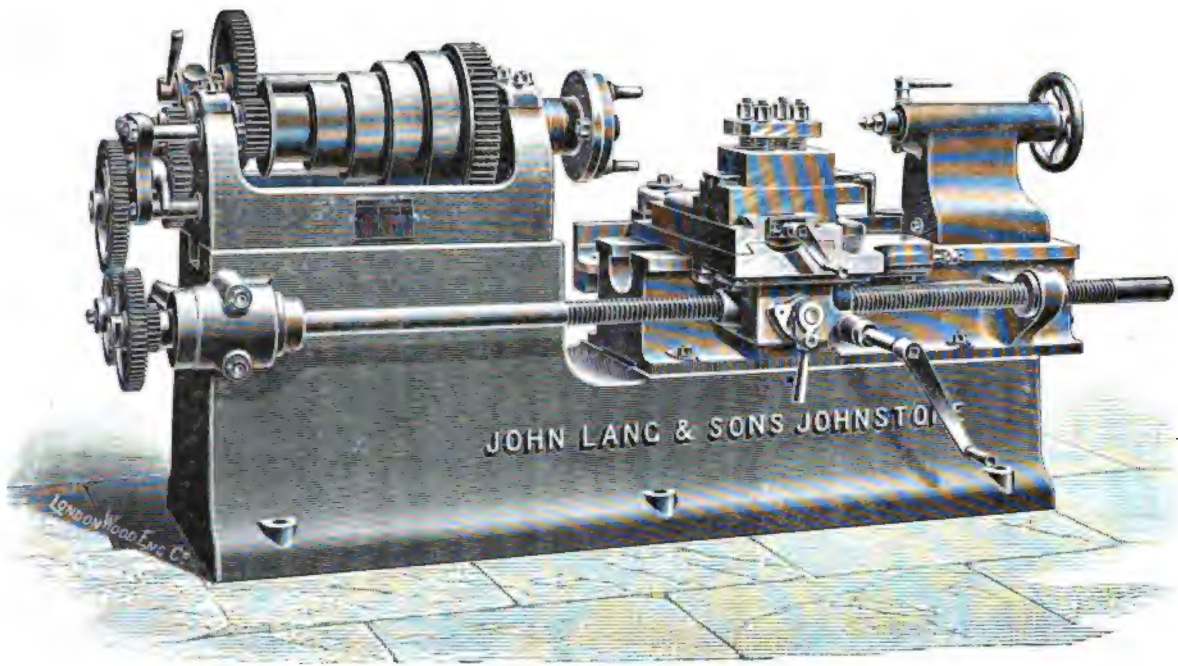


18″ CENTRE SLIDING AND SURFACING LATHE.

springing under the action of the tool, an adjustable stay is attached to the saddle, which, however, can be removed at any time. The swing frame and train of wheels for screw cutting are clearly shown, but in this case the latter are out of gear with the main spindle from which they derive their motion. These wheels range from 15 to 120 teeth, advancing by 5 teeth for each, and may be used in various combinations for mere sliding, if necessary, or for screw cutting. To save time in calculating the train of gearing for each pitch of screw, etc., a full table is supplied with each machine, which gives at a glance the required set of wheels. The *gap*, as shown in the view, is covered with a portable piece of the main slide, but this can be removed when any object of large diameter has to be faced, for which a large face-plate becomes necessary.

There are a few peculiar applications of the turners' art of a very interesting and useful character. These include the turning of screws or shafts perhaps much too long for the longest lathe in the shop, and also rope gear fly wheels up to 32 feet diameter, 15 feet width, and 130 tons in weight *without* the aid of a lathe. To these, however, we need not refer, as they chiefly belong to the heavy main driving engine branch of engineering.

For the systematic turning and boring not only of parallel work, but of tapered details, such as cocks, etc., of all sizes for steam or water purposes, the 10″ centre *Taper Turning* and *Screw Cutting Lathe*, shown in the plate on next page, is found very useful, everything being so designed as to ensure absolute interchangeability. The length of the bed is 7′ 0″, movable bed 4′ 0″, and when the guide screw is withdrawn, and a 20″ face-plate and other parts adjusted to suit, work 42″ diameter can be operated upon with ease.



10" CENTRE TAPER AND SCREW CUTTING LATHE.

As workshop economy depends greatly upon the velocity with which machines are driven, so that on the one hand the tools are not injured by unduly severe treatment, and on the other the output restricted, we give adjacently a Table, by Messrs. John Lang & Sons, showing the revolutions made by lathes compared with their cutting speed. By this means, the turner knowing the number of revolutions the lathe is making, and the diameter of work to be operated upon, can tell at a glance the cutting speed in feet per minute, and thus be enabled to drive his machine to the best advantage.

TABLE SHOWING THE REVOLUTIONS MADE BY LATHES AS COMPARED WITH THEIR CUTTING SPEED.

Diameter in Inches.	Revolutions at a speed of 15 feet per minute.	Revolutions at a speed of 20 feet per minute.	Revolutions at a speed of 25 feet per minute.	Revolutions at a speed of 30 feet per minute.
1	57·1	76·7	95·4	114·2
1½	38·2	50·9	63·6	76·4
2	28·5	38·3	47·7	57·2
2½	22·8	30·6	38·1	45·7
3	19·0	25·5	31·8	38·1
3½	16·3	21·9	27·2	32·6
4	14·2	19·1	23·8	28·6
4½	12·7	17·0	21·2	25·4
5	11·4	15·3	19·0	22·8
6	9·5	12·7	15·9	19·0
7	8·1	10·9	13·6	16·3
8	7·1	9·5	11·9	14·3
9	6·3	8·5	10·6	12·7
10	5·7	7·6	9·5	11·4
12	4·7	6·4	7·9	9·5
14	4·0	5·4	6·8	8·1
16	3·5	4·7	5·9	7·1
20	2·8	3·8	4·7	5·7
30	1·9	2·5	3·1	3·8
40	1·4	1·9	2·3	2·8
50	1·1	1·5	1·9	2·2

The unique value of the lathe as a constructive machine of endless variety may be gathered from the fact that without its aid mechanical engineering could hardly have existed, and if this had been the case we should, even now, be no farther advanced in practical science, or in travelling or manufacturing resources, than the ancients. Hence, we may well hold in supreme estimation a machine which monarchises all others, and is productive of the greatest benefits to the world at large.

The *Spring Shop* which now rises to view as we move onwards, is in every way capable of dealing with enormous quantities and varied descriptions of work. In this shop men are employed in bending and tempering steel plates, and building them up into springs, which are to be securely fastened in the centre with suitable hoops or buckles. These, when expanded by heat, are loosely slipped on to their places, then hydraulic-pressed on the sides and ends, and shrunk on the loose springs until their plates are rigidly bound together. Owing to the peculiar shapes of the buckles, and also of the finished springs, it was formerly very difficult to separate them for repair purposes, hence hydraulic power came to be used instead of sledge hammering. By the new process, the springs and their hoops are silently and rapidly disconnected, whilst at the same time injury to the metal is avoided.

The importance of having all the rolling stock springs carefully made, tested, and adjusted when in position, may be gathered from the fact that the smooth running, and indeed the safety of the carriages depends very much upon them. To ensure the necessary perfection of material, workmanship, and design, every spring is tested in a hydraulic machine whose power is sufficient to flatten it out of curve to a standard pressure of so many tons, with

as much apparent ease, too, as if it had been of india-rubber. Finally, to enable the drawing office authorities to know exactly the *experimental* strength of all kinds of springs, full records are kept for this purpose.

The *Signal Fitting Shop* is a very interesting portion of the works, which greatly overrules the safety of the whole railway system. This shop is 280 feet in length by 85 feet in width, the machinery contained in it being driven by an Otto gas engine of 48 horse power. There is plenty of *steam* power to be had adjacently, but as this department is often busy when the others are at rest, the gas engine is found very convenient and economical.

One side of the shop is devoted to the preparation of signal posts, which are received from the sawmill cut to the proper dimensions and ready for fitting. These posts are of timber, varying in size from 9″ to 15″ square at the bottom end, and tapering to 6″ square at the top, the length varying according to circumstances. The whole shop, however, is fully occupied in executing all the delicate operations that enable complete sets of signalling apparatus, with their surrounding gear, to be built together ready for fixing in position on the line. This involves the application of the same gauge and templet system which prevails in other departments of the works, and which, combined with recent improvements, has greatly reduced the cost.

One example of this will be sufficient to indicate how, amongst many other details, beneficial alterations have been made in the long rods for working the signals, etc., to be seen at any station. When formerly made of ordinary wrought iron gas pipes, screw-jointed in long lengths to each other, they were often weakened by internal corrosion that could not easily be detected. Square steel rods of

channel section are therefore now used instead, with the *hollow* side downwards, partly for strength and partly to avoid being receptacles for water. These rods are rolled at Crewe to a standard section in large quantities; then sawn to 18′ 0″ lengths, drilled in a multiple machine, fish-plated to each other, and after receiving one coat of red lead and another of red oxide paint, will last a long time uninjured by the weather.

Some idea may be formed of the amount of new work to be executed, and old work to be maintained in good order by this department alone, when it is stated that the signalling of the entire London and North-Western railway system as it stands to-day, has involved the erection of at least 1,600 cabins, and the application of 36,000 levers and 18,500 signals. In all this we have again abundant evidence of the power of the Crewe establishment to accelerate to the utmost, and with the greatest efficiency, the construction of those details upon which the safety and economical working of the various lines so much depend.

It is not too much to say that without a proper signal system, and signals that are kept in perfect working order under all circumstances, much of the skill bestowed on the line and rolling stock would be neutralised, as some of the most dreadful accidents of the past have abundantly proved. To avoid these dangers, the greatest vigilance is exercised over the vast and complicated array of "home," "distant," "junction," "platform starting," "advanced starting," etc., signals and interlocking apparatus that guide the working of the various lines, so that not a single point rod or signal arm can fail to answer the action of the lever connected with it.

To ensure all this, the whole of the London and North-

Western Railway system is divided into thirteen districts, each of which is in charge of an inspector. These officers are assisted by 21 sub-inspectors and foremen, and have under their orders 74 "charge-men" and 460 workmen. The above districts are subdivided into lengths, and each length is placed in charge of a charge-man and an assistant, who visit every signal cabin on their station once a fortnight, clean and oil the fittings of each signal and point, execute small repairs or renewals which it is possible to carry out during their visit, and report to the inspector of the district any which they may find necessary, but which they themselves are unable to deal with on the spot. In every signal cabin the name and private address of the charge-man who is responsible for it are posted, and it is the duty of the signalman to report to him every failure or defect that may become apparent during the intervals of his visits, sending at the same time a duplicate of the report to the inspector of the district.

In addition to this, every cabin is visited once a month by a fitter and his assistant, whose duty is to carefully examine, clean, oil, and, if necessary, repair the locking apparatus, particulars of the work done being entered in a monthly report, which is sent through the district inspector to the head office at Crewe. Heavy repairs and renewals are executed by an extra gang attached to each district, in charge of a responsible foreman, the most stringent rules being laid down as to the manner in which the work is to he carried out, so as to provide for the safe and uninterrupted conduct of the traffic during the time it is going on.

With the object of maintaining the permanent way and works in the most complete order, a similar but much more extensive system of organisation has been found necessary, a small army of men being employed for this

purpose. So thoroughly are the various lines thus supervised that not even a lineal yard of rail, with its fish plates, chairs, sleepers, etc., escapes the lynx-eyed vigilance of those who, unknown to the public, watch over their safety from day to day, and at once rectify any fault that may appear. As the above "works" include bridges, tunnels, viaducts, stations, and all kinds of buildings, it will be seen that the safe maintenance of a great line is a highly responsible and most comprehensive undertaking, and one which involves the constant application of some of the highest branches of practical and theoretical science in infinitely varied forms.

CHAPTER XVIII.

SPECIAL LABOUR SAVING MACHINERY AT THE CREWE WORKS.—THE GREAT MACHINE SHOP.

Impression on Visitors—Extent and Variety of its Operations—Automatic Detail Cleaning Process—Utilisation of Waste Products—Successive developments of Boring Machines—Shaping Machines—Side Planers—Screwing Machines—Fastenings of Machinery—Multiple Screw Cutting and Sliding Machine—Piston Rod Grinding Machine—Hollow Spindle Capstan Rest Lathe—Brass Finishers' Turret Lathe—Milling Machines in Modern Practice—Milling Cutters and their Treatment—Useful Cutter Tables for the Workshop.

A walk, even in the most casual manner, through this portion of the Crewe Works, accentuates all that we have previously remarked regarding the value of special labour-saving machinery where there is much of a repetition nature to be done, and perhaps nowhere in the world is this more apparent than in the shop we have now entered. To non-professionals, as well as to engineers, a visit to any vast modern finishing machine shop must be profoundly interesting, especially when compared with the less refined portions of the establishment, which, however, to the experienced, convey much more than many would suppose.

The first thing that strikes one upon entering the former is the forest of belts, drums, pulleys, countershafts, etc, with all their accessories, that transmit varying velocities to the machines, quite independent of their own wheel gearing, which further produces similar results. In gigantic shops, such as those at Sir Joseph Whitworth's, and elsewhere, the ground floor machines are frequently of

colossal dimensions, and with plenty of space around them to allow for the transport and manipulation of heavy castings and forgings. At Crewe, however, the department we are now surveying, extensive as it certainly is, would be much greater were it not that an enormous number of the previously noted larger and medium sized machines had been placed in other parts of the works for convenience. It therefore happens that the magnificent array of beautiful mechanisms now before us are employed chiefly on large quantities of locomotive, tender, and other details of very varied character, though of lesser dimensions than are as a rule to be found elsewhere.

A glance in an all round direction reveals at once the nature of the operations here carried out. To the right, a number of cylinders are being bored to a dead true surface, whilst others are having the ports slotted and valve faces planed in a manner unknown to the marine fraternity. A lot of axle boxes are undergoing exterior planing on one machine, and a number of slide valves on another. Coupling rods are being milled all round in faultless fashion. Connecting rods are being either drilled, milled, or planed to absolute perfection. Piston rods, valve rods, and all kinds of cylindrical gear are in the hands of numerous turners, whose lathes are rapidly reducing them from rough forgings to finished work. Beside all these there is to be found, lying about on the floor, an extensive and heterogeneous assortment of gear for inside and outside work throughout the whole of the London and North-western railway system, which has to be renewed, rectified, touched up, titivated, and so on, before each part can be erected in a new structure or replaced in position in an old one.

We are pleased here to note a most important fact connected with all *repair* work at Crewe. In places not so

fully organised, details that have been taken out of engines for amendment are usually in a most abominable state of black greasy dirt, which has to be removed by hand as far as possible, thus causing loss of time and very disagreeable employment to the workman or to the aristocratic apprentice who may be put "on the job."

With the object of rectifying this serious evil, boiling pans have been fitted up for economically and effectually removing the oil and grease from every part after disconnection, the grease being collected and manufactured into soap. From this it will be seen how an apparently insignificant operation can be turned into a source of revenue, not to mention the subsidiary advantages to which we have just referred. Truly the Crewe establishment is a wonderful place from beginning to end! This, however, need not surprise anyone when the vastness of the undertaking is considered, and also the highly talented Engineers-in-Chief Mr. Trevithick, Mr. Ramsbottom, and the present Mr. Webb, who have in their own way introduced most important changes which in other Works have been more or less overlooked.

As we gaze around, we observe many of our old and time honoured friends in improved forms, and, in very numerous cases, specially altered double, treble, and quadruple arrangements of the same.

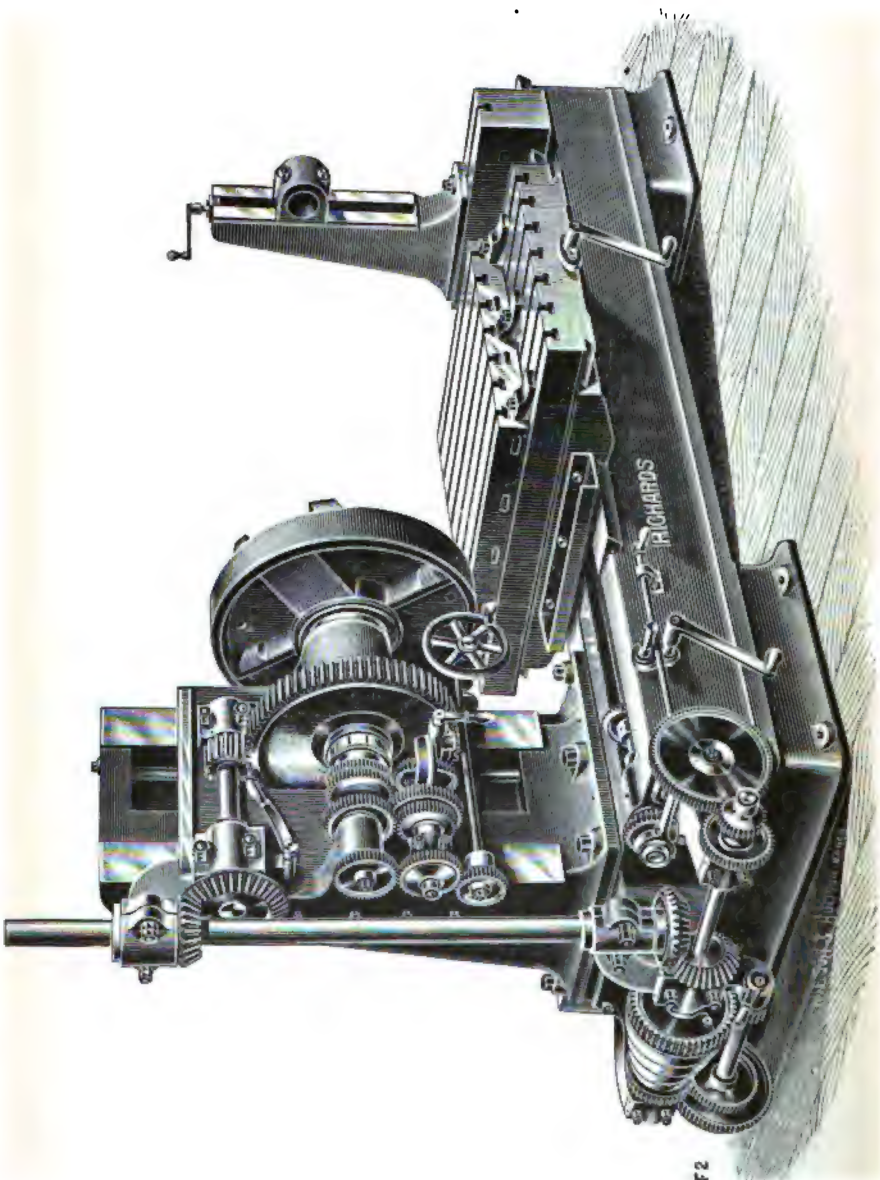
The original hand drill has now become developed by successive inventors into a powerful drilling machine. This, again, has been promoted to the ranks of the very important family of *Borers*, which may be said to begin at the driller of say 3" hole capacity, and end at the colossal machines for boring cylinders up to say 120" diameter, all sorts of which, for every conceivable purpose, being now constantly employed.

One of the most useful of recent type *Boring and Facing Machines* for general as well as for special work, is that shown on page 314, which possesses several excellent features. The lower table is longitudinally, and the upper one transversely, traversable, while at the same time the boring head has a 20″ vertical motion for adjustment. This head is capable of edge turning and facing flanges or other circular objects up to 24″ diameter, but by an extension of the tool holder, as much as 32″ diameter can be taken in.

The table has a longitudinal motion of 4′ 6″, and hence the capabilities of the machine in this direction may be clearly understood. By placing a *revolving table* on the top of the upper one, its utility at once becomes greatly enhanced, as angled, bent, and irregularly shaped pipes, etc., can, at one setting, have their flanges turned and faced in any position with the greatest accuracy.

By the addition of a *slide rest*, and by the substitution of a bolt-holed face-plate instead of the cutter disc now on the spindle, wheels and pulleys can be bored and turned as in the lathe. If pump or small cylinder boring is required, all that has to be done is to place a solid boring bar in the machine, the outer end of which is carried by the vertically adjustable stay bracket bearing. Here the comprehensive nature of this machine comes so fully into view that further explanation is unnecessary.

The ordinary *Drilling Machine*, in variously improved forms, now permeates the whole domain of Engineering. Its powers are not merely confined to the formation of bolt, pin, and rivet holes, but, in the absence of a punching machine, are additionally employed in cutting apertures of all kinds in plates, upon the perforated postage stamp principle, after which the piece to be removed can easily be taken out. The burglar knows this elementary truth



BORING AND FACING MACHINE.

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when he tries to rob your treasure laden safe, only, however, to find himself baffled by hard steel plates, so hard that even his own special drills cannot touch them.

A very useful specimen of a *Double Geared Swing Table Drilling Machine* by Messrs. Hetherington & Sons, is illustrated in the Plate on next page. This machine will bore holes up to 6″ diameter by means of a cutter bar in the centre of objects, and drill up to 2¼″ diameter from the solid.

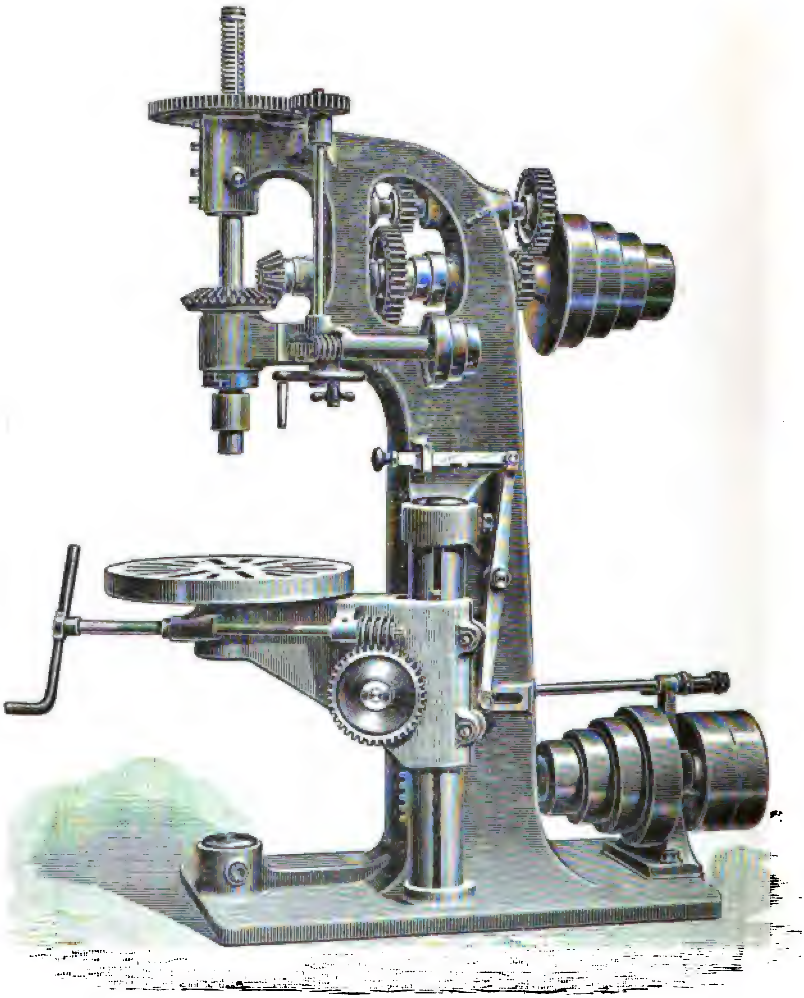
The table is 24″ diameter, and is capable of being adjusted and locked in any position, or of being swung entirely to one side. Its vertical motion is 14″, and when *deep* objects have to be bored, it can be removed from the swinging arm and placed in the socket on base plate. The arrangements of the feed, back motion, and belt gear, are complete in themselves as may be seen.

Another class of greatly improved machines of this nature is that for *Horizontal Boring and Tapping*, an example of which is given on page 317. This machine is also very useful for stud inserting and trimming, and general operations.

Its range may be gathered from the fact that it will bore holes from ½″ to 20″ diameter in any part of an area 36″ square. The spindle is 4″ diameter, and has 30″ travel by rack and pinion, while its slide has a 36″ vertical travel, and is balanced by means of a weight inside the column. The table is 48″ long by 28″ in width, and traversable both ways, the outer bearing for boring bar having an 18″ vertical traverse, the bracket which carries it being removable when necessary. There are also six changes of feed from 118 to 16 revolutions of spindle per inch of travel.

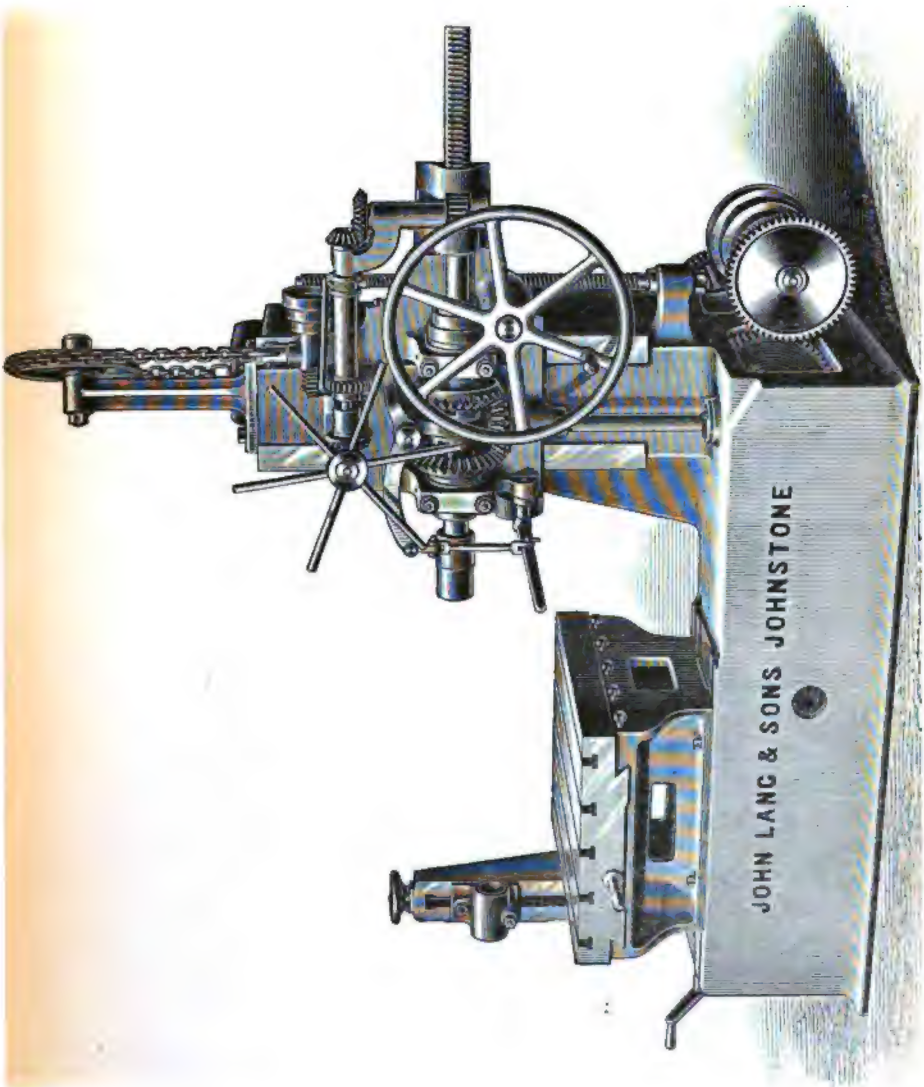
Extra gear is also fitted when required, and this in-

cludes a 36″ square table capable of swivelling on a pivot in the ordinary table, and having a key for fixing it in four



DOUBLE GEARED SWING TABLE DRILLING MACHINE.

positions absolutely square with each other, so that work may be machined at either end or on the sides at one



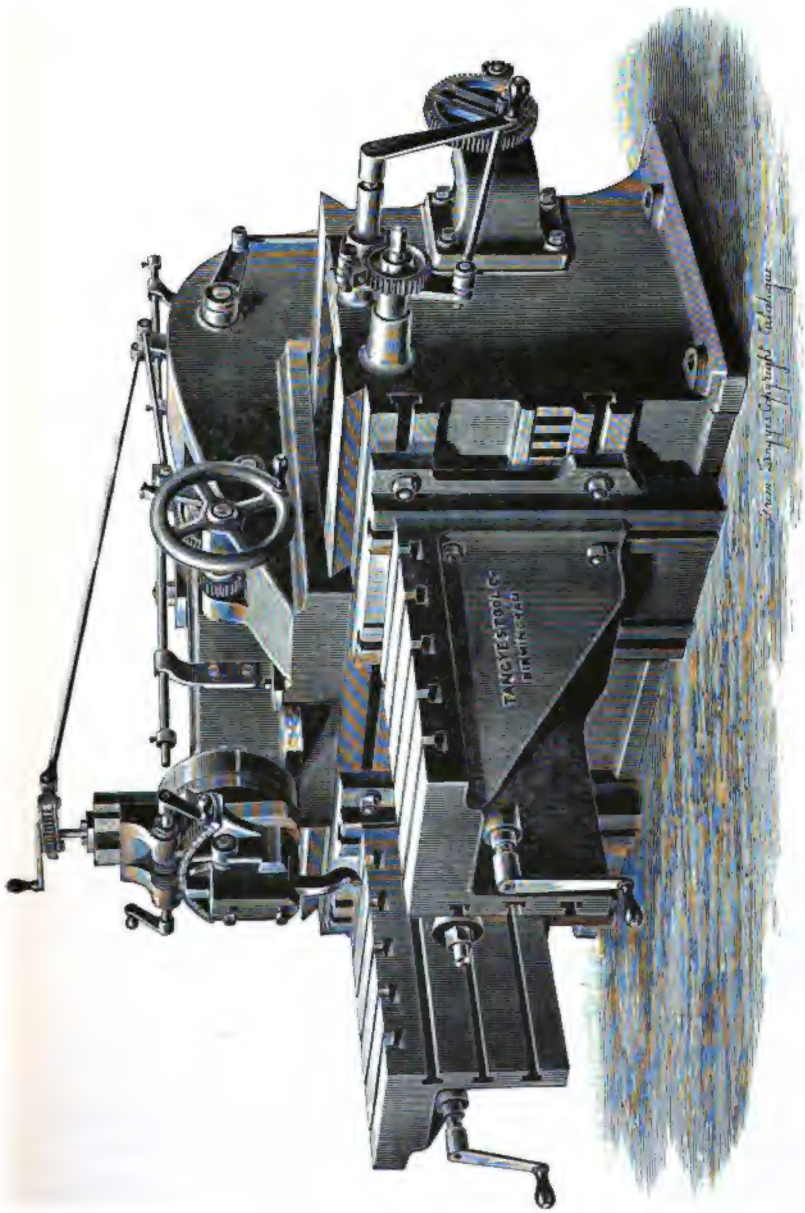
HORIZONTAL BORING AND TAPPING MACHINE.

setting, a surfacing tool being used for that purpose. In some cases, however, the *boring standard* works on a slide for transverse adjustment, the table forming part of the bed plate and having the usual T grooves for bolts.

In all Engineering establishments there is a large amount of small and medium sized work that is of too variable a nature to be economically executed by planers and slotters. This led to the introduction of the *Shaping Machine*, which combines the actions of both in a very satisfactory manner, especially where details are of a complicated, or almost circular, or otherwise irregular form. These machines may be either of the single-headed type, as shown in the adjacent Plate, or of the duplex class, which is extremely handy for work such as planing the two ends of a connecting rod, etc., at one time.

In all cases there is a quick return motion of the rams, which are capable of adjustment in every way to suit work on any part of the tables. These latter are adjustable along the bed, and also vertically by means of screws worked by the handles in front. For small gear otherwise difficult to secure in position, parallel vices bolted to the tables come in most usefully, and when the mandrel between the latter has its reversed cones for instantaneous setting pressed against each side of the eye of a lever, its boss can be automatically finished with little trouble. The ram has variable strokes up to 21″, its tool box having a vertical slide capable of swivelling for angular cuts, whilst the box itself can be radially traversed by a worm segment for the purpose of shaping internal curves.

A modification of this class of machine is also made for planing several surfaces at different angles in valve boxes and other castings at one setting. Here, however, circular



SHAPING MACHINE.

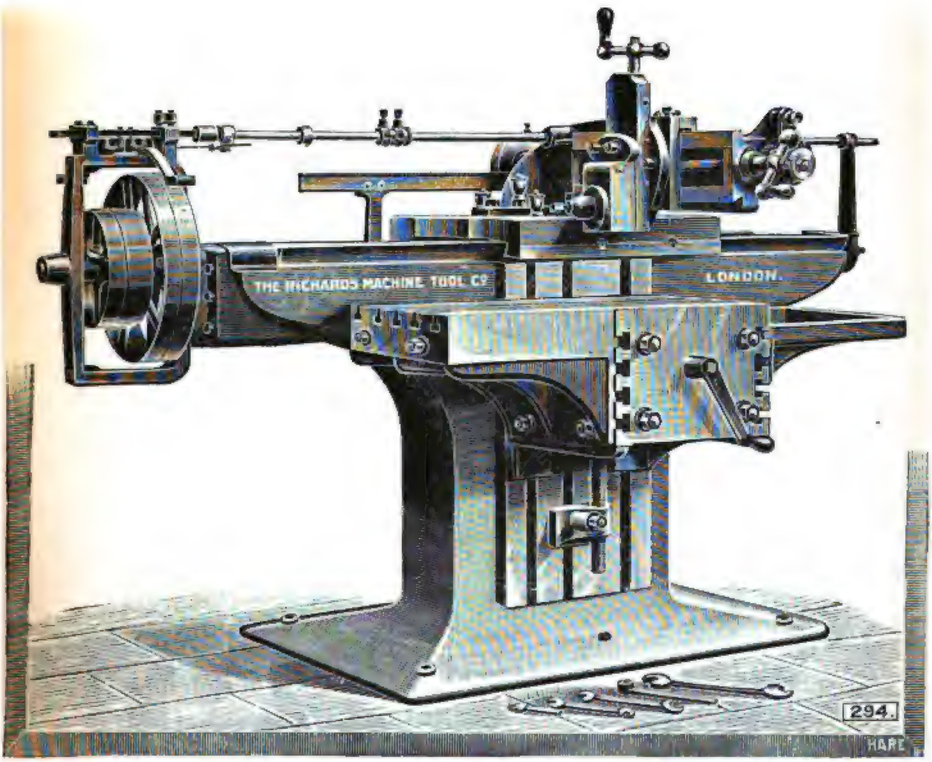
tables with vertical faces, capable of circumferential movement are employed instead of those shown in the Plate.

The *Side Planing* system differs from both of the above, as shown in the opposite view. It will be seen that while the overhung arm has no transverse motion, it is fitted with a tool box and slide which do all the work, as the arm is traversed longitudinally by means of a guide screw driven by the end pulleys. This machine is capable of planing a surface 18″ wide by 40″ in length, but in the largest size these dimensions are as great as 40″ and 30′ 0″, two tables being used, and also two tool boxes. For work that cannot otherwise be manipulated a pit in front becomes very useful.

It will be noted that the tool shown in the machine on page 319 is forged out of a square bar, as it is most suitable for the purpose. This kind of tool is extensively used for heavy cutting in lathes and planers owing to its power to bear even the most severe straining. For general work, however, of a lighter character, special tool holders are very popular, as they are so well adapted for round and other sections of bar steel which need no forging whatever. Here the grindstone does all that is needed when used by the attendant who keeps the tools in order.

In all engineering establishments there is an enormous amount of *Screw cutting* of a minor character which has to be performed by special machinery, quite apart from the heavier class generally executed in the lathe. Long ago, a great deal of the former was made by hand tools, or in very slow working machines, until advanced science showed how a much larger quantity of better work could be done in less time. Thus it came to pass that the screwer of to-day is so greatly superior to his early predecessors.

There is no method of fixing the parts of machinery together that is so simple, so efficient, or so easily adaptable to the different phases of engineering practice as that of the bolt and nut. Of course, we fully recognise the indispensability of the gib and cottar, or the latter alone



SIDE PLANING MACHINE.

in many cases, but for all round suitability on a truly universal scale there is nothing to equal the first named attachment, which has a history quite its own.

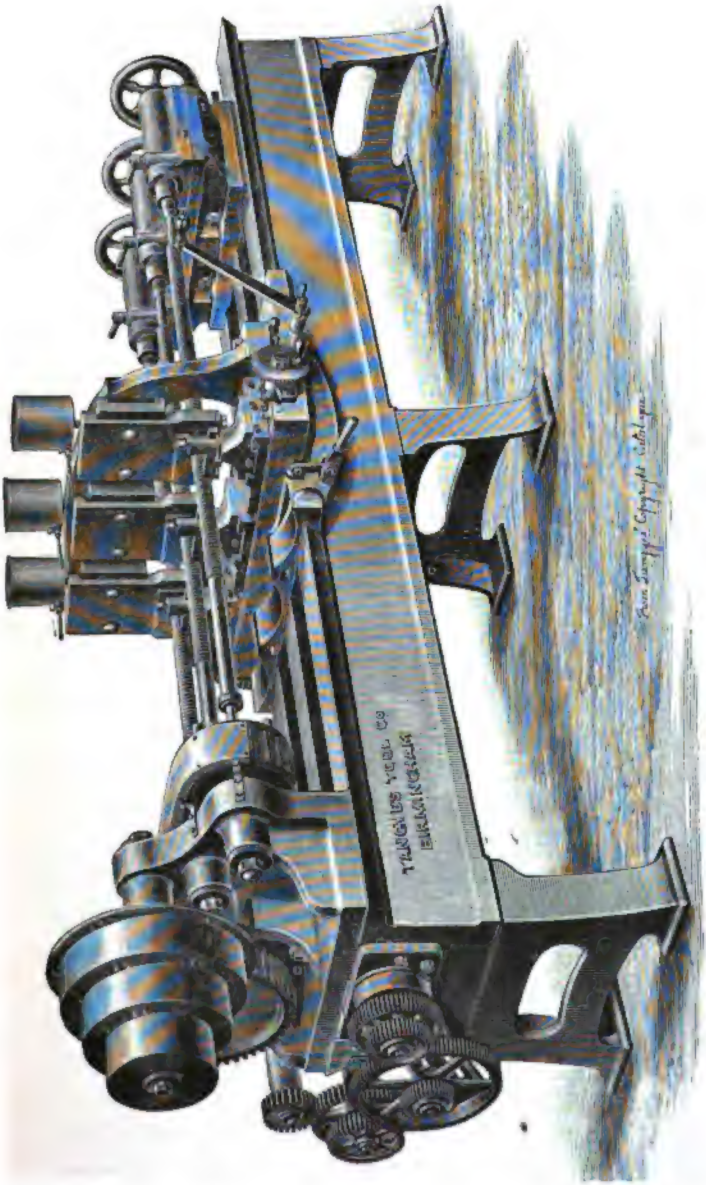
In early times the threads of screws were irregularly made, according to the ideas of the designers. This,

however, caused great inconvenience when bolts and nuts of the same size from different firms wonld not interchangeably fit each other. As a means of rectifying this serious evil, Mr. Whitworth experimented with a large number of screws so that he might ascertain their best form and relative number of threads per inch. When this was done, he made them of all diameters to fit a standard set of gauges, which in a short period became universally popular. Thus it came to pass that a "one inch," or any other nut made in England, accurately fitted a bolt of the same diameter from Bombay, or Melbourne, etc., to the very great advantage of the world at large.

The foregoing remarks upon Screwing Machines refer to those employed in the manufacture of bolts say from ⅛" to 3½" diameter, which, in the smallest sizes, are made in enormous numbers. For larger screws, however, up to about 16" diameter, and 70 feet in length, the work of the lathe must ever reign supreme.

Wood Screws are now so extensively employed for railway carriage and innumerable other purposes that a cunningly devised machine is now used by means of which the peculiarly shaped threads are *rolled* out of a solid red hot steel blank in a very rapid and perfect manner, thus producing stronger threads than when cut by a lathe tool, and saving at the same time about ten per cent of material.

As enormous quantities of carriage and wagon screw couplings, etc., are made in the Crewe establishment, it became necessary to have some more rapid method of manipulation than that supplied by the ordinary lathe. With this in view, the *Multiple Screw Cutting and Sliding Machine* was introduced, one of which is illustrated on next page with work in operation placed between the centres. These couplings are extremely simple and efficient, and



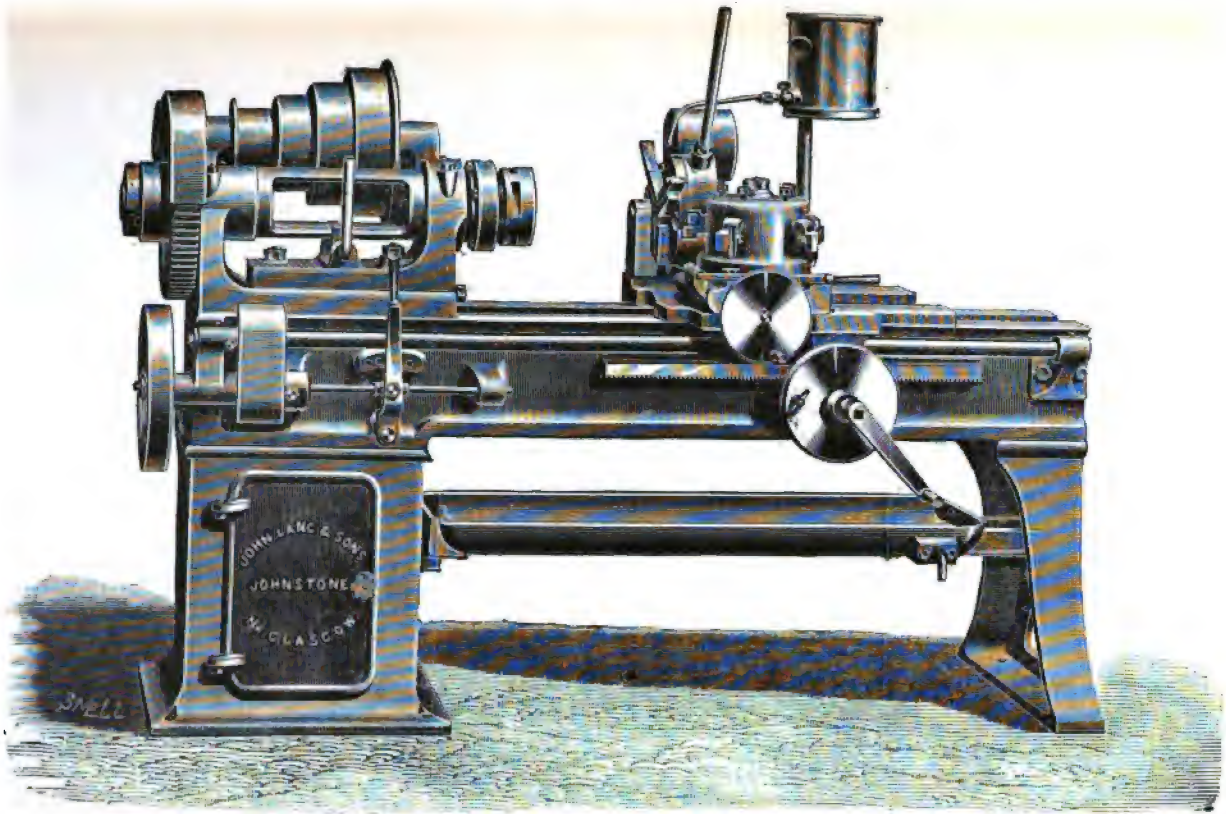
MULTIPLE SCREW CUTTING AND SLIDING MACHINE.

are quickly produced by means of the above machine, whose height of centres is 10″ and length of bed 12′ 0″.

The last named appliance is used quite as much for turning piston rods by the hundred, as for cutting interchangeable screws by the thousand. Here, however, it may be said that with the former, as with all other similar details, the supreme skill of the workman is concentrated upon the *finishing* cut, which may either make or mar the fitting of these to their connections. Formerly this was done by a scraping tool which did not produce sufficiently accurate results, hence the *Piston Rod Grinding Machine* was introduced, which, after a rod has been turned very nearly to the size, finishes it to an exquisite fit. Further, it so operates in a similar manner upon old and worn rods, that lathe work in their case becomes unnecessary. The same principle is applied with great effect upon the cylindrical and extremely delicate gauges so indispensable to the turner, etc.

In these machines the piston or other rod is made to revolve rapidly, whilst a reciprocating and contrarily revolving emery wheel grinds it to perfection.

For operating upon the innumerable varieties of brass fittings and small details used throughout the realms of engineering, and particularly at Crewe, the *Hollow Spindle Capstan Rest Lathe* is of paramount importance, as each of its five tools in rotation can be brought instantly into play, thus avoiding the loss of time formerly incurred by having to change the cutters for every perhaps momentary movement. By the assistance of this machine immense quantities of studs, lever pins with heads and screws, special bolts and screws, etc., are formed at one setting out of rolled bars instead of forgings, which are passed through the hollow spindle and held fast in position by conical grips.



HOLLOW SPINDLE CAPSTAN REST LATHE.

A view of one of these lathes is given on previous page. The sliding carriage is self acting, and by means of Messrs. Lang's handle feed motion the rate of feed may be altered without even withdrawing the tool, whose advance of $\frac{1}{32}''$, $\frac{1}{24}''$ or $\frac{1}{16}''$, per revolution of spindle, is immediately obtained.

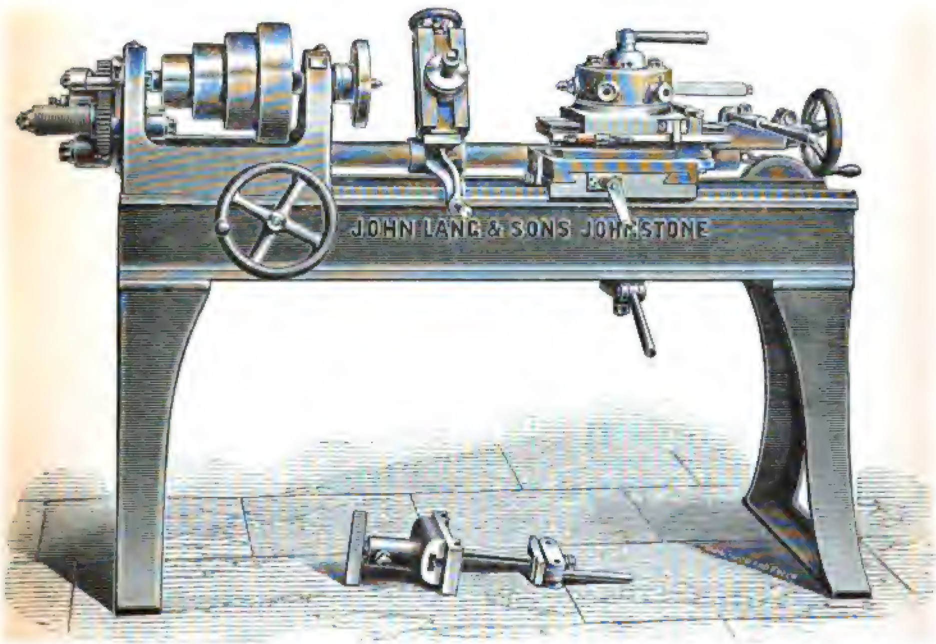
The screwing gear is made to swing out of the way when not required, and the die holder is so constructed that screwing up to a shoulder can easily be performed. The dies are cut from a bar of special shape and fit into the slides of screwing head without machining, and as the former are in long lengths, the threads may be recut many times by means of master taps.

The conical grips mentioned above are made to hold bars advancing by $\frac{1}{8}''$ from $\frac{1}{2}''$ to 2" diameter, and the screwing dies are similarly suited to screws from $\frac{1}{4}''$ to $1\frac{1}{8}''$ diameter. Amongst the extra gear supplied are a shifting head with its usual connections, so that work may be turned or screwed between the centres, as in other machines. It may further be observed that the wheels in front of the bed are protected by polished shields, and the others are similarly covered, whilst a trough underneath collects all the cuttings. Part of the framing is formed into a tool box.

The last of the machines of this class to which we shall refer is the 8" centre *Brass Finishers' Turret Lathe* adjacently shown. For the rapid manipulation of brass details of all kinds that are required for railway and other work, this machine, variously arranged, is invaluable. Here again, the turret or capstan rest proves itself to be one of the best inventions of the age, as previously explained. The turret slide is also capable of being used as a shifting head with centre, and of being locked in any position, the slide

beneath it having a cross surfacing motion and stop arrangement for setting the tools, so as to cut automatically to the same diameter in repetition style.

For work of this nature the screws are usually of the fine or gas thread order, the swinging tool slide on shaft doing all that is needed in this respect. At the end of this



BRASS FINISHERS' TURRET LATHE.

shaft a lever, having a brass open sided nut attached to it, can be thrown into gear with a short guide screw as shown, which gives the correct pitch movement to the cutting tool, the hand rest shown on the floor enabling finishing touches of any kind to be put in most conveniently. By this means screws of 10, 11, 12, 14, 16, and 18 threads per

inch can be thrown off speedily. The additional parts include a 14″ diameter four jaw expanding chuck, and all the usual gear for general work.

By the aid of the *Capstan Rest* in the above machines, as we have tried to show, small details may be turned, bored, notched, cut, chamfered, and screwed at one setting with the greatest ease, and this will, we hope, sufficiently indicate the generally useful application of one of the best labour-savers of the day. The foregoing remarks upon lathes, planers, slotters, and shapers alike have reference to machines whose special feature is the power of taking more or less heavy cuts. We now, however, come to those of a totally different kind.

The *Milling Machine*, to which we refer, is peculiarly adapted for performing a great variety of delicate and interchangeable work that cannot be so well or so economically done by any other process, without the intervention of highly skilled labour.

This tool has been employed in England for about one hundred years, but until recently only on a limited scale, owing to the difficulty and expense of softening, sharpening, and re-tempering the cutters, the last of which processes frequently twisted them out of truth. Now, however, the introduction of emery grinding machines has enabled their teeth to be easily and accurately trimmed to standard sizes without being softened, thus forcibly exemplifying the immense benefit that may be conferred by one good invention upon another. At the same time it should be stated that various alterations in the original form of the teeth enables this result to be accomplished.

Although the Miller is, after all, only a nibbling machine, it compensates in a great degree for this defect not only by continuity of action, but by a higher rate of speed,

owing to the edges of the tool being successively relieved from contact with the metal operated upon, and thus more fully exposed to the cooling action of water. Hence it follows that the velocity of these edges may be much greater than that of other tools of the ordinary description.

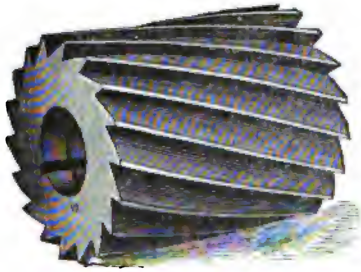
There is still something to be learnt respecting the most economical rates of speed and feed for *Milling Cutters* to suit the various metals now in use, but advancing practice is gradually showing how this operation can be most efficiently performed. The same practice is also indicating the necessity of designing details, when possible, to suit the powers of this machine, instead of the lathe, planer, and slotter conjointly, as is generally the case. As screw-cutting lathes are provided with tables of change wheels for various pitches of thread, so that the turner can see at a glance the required arrangement of gearing, milling machines should be similarly furnished with tables giving the number of revolutions per inch of feed for cutters of all diameters, and depths and widths of cut—roughing and finishing—for brass, cast iron, wrought iron, and steel, the value of which has now been extensively appreciated.

Specimens of four of these in general favour, by Messrs. Brown and Sharpe, are adjacently shown, all of which can be accurately sharpened to the last without softening, by means of special *Cutter Grinding Machines*.

The cylindrical or spiral cutter A is employed in a great variety of plain work, such as the bosses and webs of cranks, levers, etc, where a high finish can be given without further trouble, and with the grain running longitudinally as it should do. Cutter B has similarly its own particular uses, and in thinner forms may be used either for slotting screwheads, or for sawing metals.

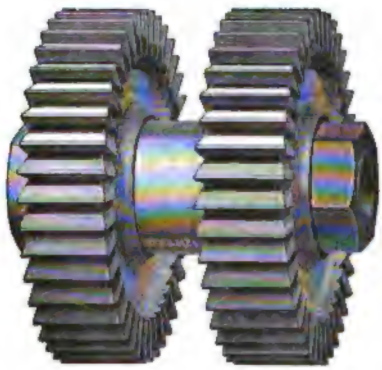
The side and face cutters C are used for purposes too

numerous to mention, variously combined or spaced, according to circumstances. The involute or gear cutter D is made to suit the thickness, depth, and curvature of

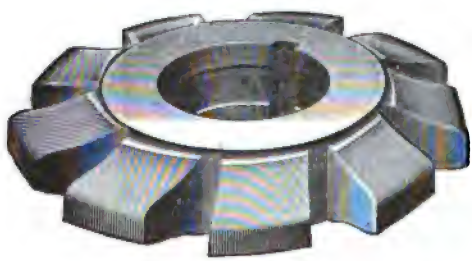


CUTTER A.

CUTTER B.



CUTTER C.



CUTTER D.

the teeth in all wheels, which can thus be shaped exactly out of the solid metal, a peculiarly bevelled cutter being used in the formation of other cutters, rhymers, etc., in general use. It may be added, however, that it is usual to shape the teeth of wheels up to about 2½" pitch by the milling machine alone, and roughly outline all others by means of the *slotting* process, on account of the extra heavy cutting required. As the above machine is now one of the most valuable of the present day, and promises to become still more so, we shall explain it fully in the next chapter.

CHAPTER XIX.

THE CREWE WORKS' LABOUR-SAVING MACHINERY.—*Cont.*

Various Applications of the Milling Machine—Its Marvellous Powers—Universal Milling Machine and its Uses—Machine for rapidly Turning Piston Rings—Large Circular Planing Machine—The Finance of Machine Application—Use and Abuse of high class Workmanship—Horizontal Boring of Wheel Tyres—Horizontal Duplex Slot Drilling Machine—Emery Grinding Machinery—Extraordinary Universal Grinder—Standard Tools—Adjustable Rhymers—Screwing Gear—Manufacture of Twist Drills—New Standard Lathe Mandrils—Measuring Machines—Decimal Measurements—Organisation of the Tool Room—Summarised Notes upon the Crewe Works.

ALTHOUGH the Milling Machine is now being extensively used for the heavy classes of work, its powers are most fully shown in places where perhaps countless thousands of small details are made from solid blank forgings or punchings. So all powerful is this machine in its own way, that there appears to be an ever widening field for its employment in every branch of engineering. This is due to the fact that a milling tool has many cutting edges which have, in finishing to gauge, so little to do that they cannot deteriorate perceptibly, whereas the finishing tool of a slotter or planer, when operating upon delicate objects, is so constantly exposed to wear, that its exactness is soon destroyed.

As the cutting of wheel teeth out of the solid is now extensively adopted, it is necessary to have machines which will do the work economically and well. Several of these are now in successful use, the most extraordinary of

them all, however, is one invented in America, and constructed by only one English firm. In this case, three or more cutters are employed at one time, according to the size of the wheel and pitch of its teeth, every movement being so arranged that when the work has been set in position and the machine started, it will automatically and unerringly go on to the end without any attention. To show its capability we may add that, whilst cutting three teeth at one time, it will finish a cast steel wheel 23" diameter and 1" pitch in from 2 to 2½ hours, the depth of cut being ¾", feed 1½" per minute, and circumferential speed of cutters 33 feet per minute.

The applications of the Miller are almost endless, but the following examples will be sufficient for the purpose. Every apprentice knows the difficulty of planing connecting rod flanged brasses in such a way as to require the least amount of hand tool fitting, by the application, however, of three milling cutters in combination, the work is done to perfection without further trouble. A much more difficult performance is the planing of accurate channel grooves for the slipper guides of small piston rods. Here, again, in the simplest manner, the Miller will, with two cutters in combination, perform this operation faultlessly to gauge, and so on endlessly.

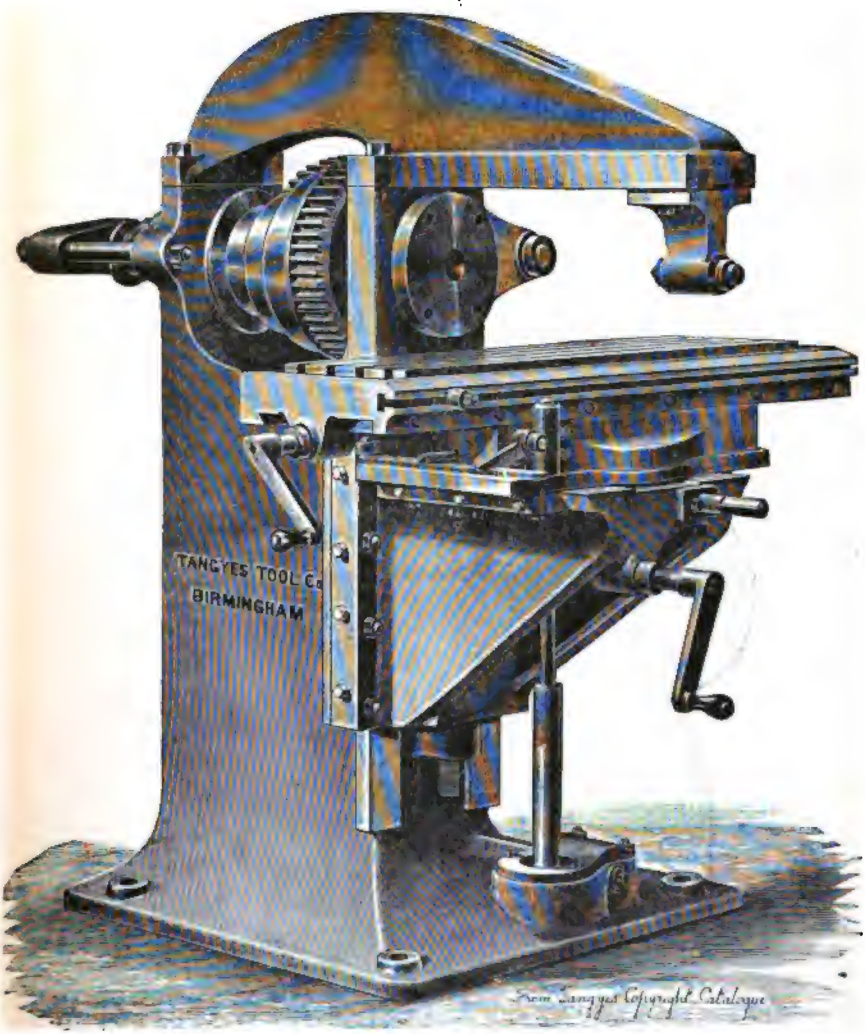
To enable a clear idea to be obtained of the marvellous powers of this class of machine in its multitudinous forms, one would require to visit places, such for instance as the splendid new establishment of the Lancashire Watch Company at Prescot, the gigantic works of the Singer Sewing Machine Company, and many others, in all of which the most delicate workmanship is executed in a style absolutely unapproachable by any other system. An inspection of various engine, and machine, and locomotive

establishments, especially the Crewe Works, will confirm this on a larger scale. Still more will this be the case in marine works, where the most powerful specimens of the Miller are engaged in cutting heavy details out of solid blocks of steel.

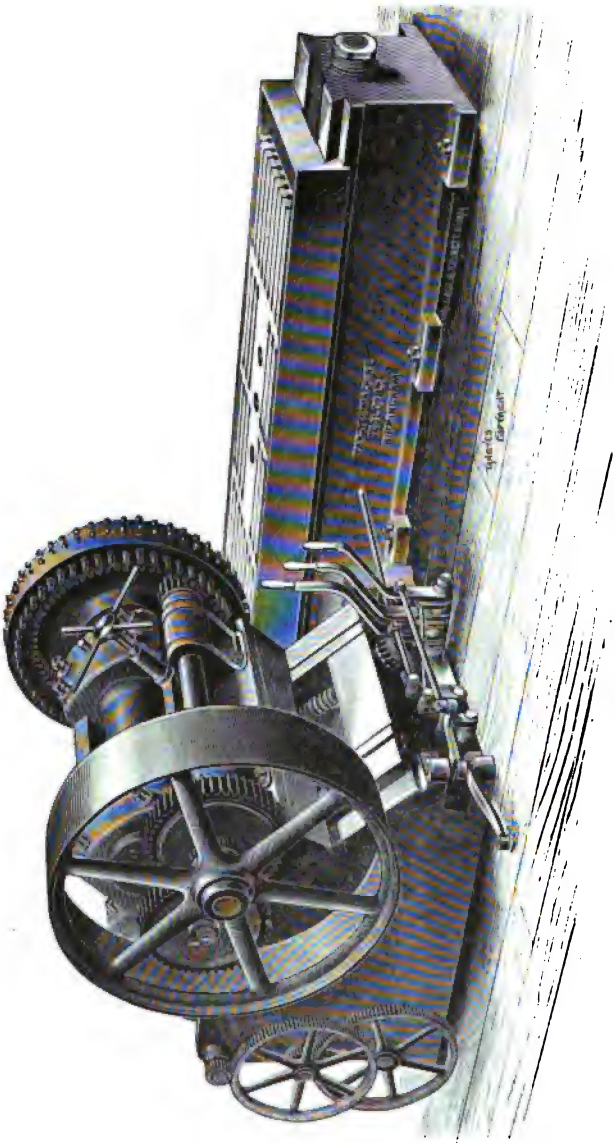
One of the simplest examples of this machine is given in the Plate opposite. When engaged in *edge* milling, a spindle with cutter of the required shape, such as that shown at A on page 330, is carried between the disc aperture and the centre at the end of the overhanging arm. The work to be operated upon is secured to the table, which is automatically traversable in either direction, and is also capable of being swivelled to any angle when required, a stop motion being employed to regulate its stroke. The feed motions are sufficiently numerous for all purposes, and when face cutting is needed, a cutter block is secured by bolts to the flange shown in the view, the overhanging arm being removed for convenience.

One of the most recent arrangements of the face-cutting system is shown in the Plate on page 336 of a *Treble Geared Machine*, which mills economically and conveniently, by means of either face or edge cutters, a great variety of surfaces. The spindle carries a face plate fitted with numerous tools, each adjustable by set screws, and 40″ diameter in the cutting circle, the headstock being diagonally and horizontally traversable by means of the two slides.

Change wheels capable of producing table feeds from 1″ to 6″ per minute accompany the machine. For ordinary heavy milling with barrel or other cutters, a strong spindle, with outside bearing attached to the bed-plate, can be used instead of the disc. It may be added that every movement of the machine is controlled by the hand levers, and



MILLING MACHINE.



TREBLE-GEARED MILLING MACHINE.

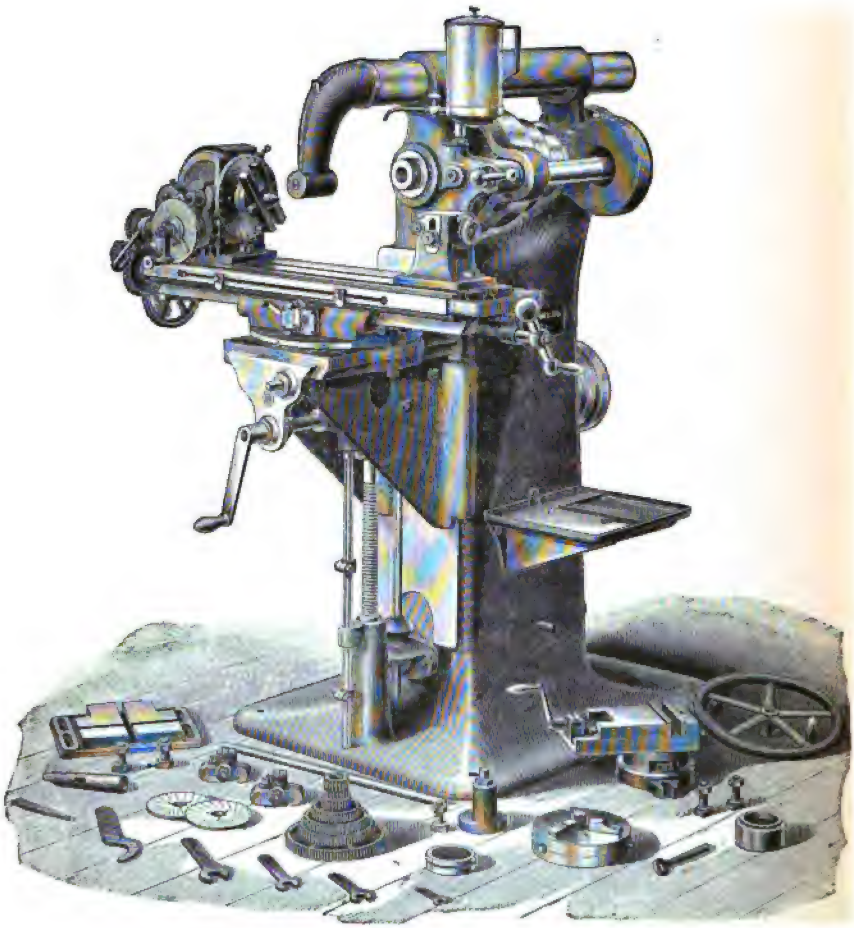
that amongst many other applications, the disc nibbling process referred to is similar to that used at Crewe and elsewhere for cutting out the webs of crank axles.

As the typical machines just referred to are very simple and excellent illustrations of a most extensive class, it may be well to give an engraving on next page of one by Messrs. Brown & Sharpe, of Rhode Island, under the title of *Universal Milling Machine*, which may be easily understood when so many details are supplemented.

Firstly, the overhanging arm, which has an adjustable centre, can be turned out of the way or removed altogether when not wanted, the distance from its own centre to centre of spindle being 5½″. The table has a working surface of 32″ by 6⅝″, a travel of 20½″, and twelve changes of feed in either direction. It has also a transverse movement of 6½″, and when required can be lowered to 17½″ from centre of spindle to suit the work to be operated upon, and, as the feed motion is centrally driven, the table can be worked by it at any angle. The spiral head to the left, and foot stock centre to the right of the table, swing 10″ in diameter, and take 15″ in length, both being capable of setting at various vertical angles.

The vice for the table swivels, and has a graduated base, and this from its very easy and effective application to small objects makes it a valuable accessory to many machines. As extreme accuracy in dividing is essential, index plates, such as those on the spiral head and also on the floor, are made capable of dividing all numbers to 100, all even numbers to 134, and all numbers divisible by 4 to 200. By means, too, of a very simple attachment to the milling spindle, its horizontal motion can be changed into a vertical or graduated angular one, according to circumstances, and this, in conjunction with the other details

referred to, enables the machine to perform extremely varied work, including the manufacture of taps, rhymers, milling cutters, and small tools in general.



UNIVERSAL MILLING MACHINE.

There are very many locomotive and other details which can be conveniently and economically milled, espe-

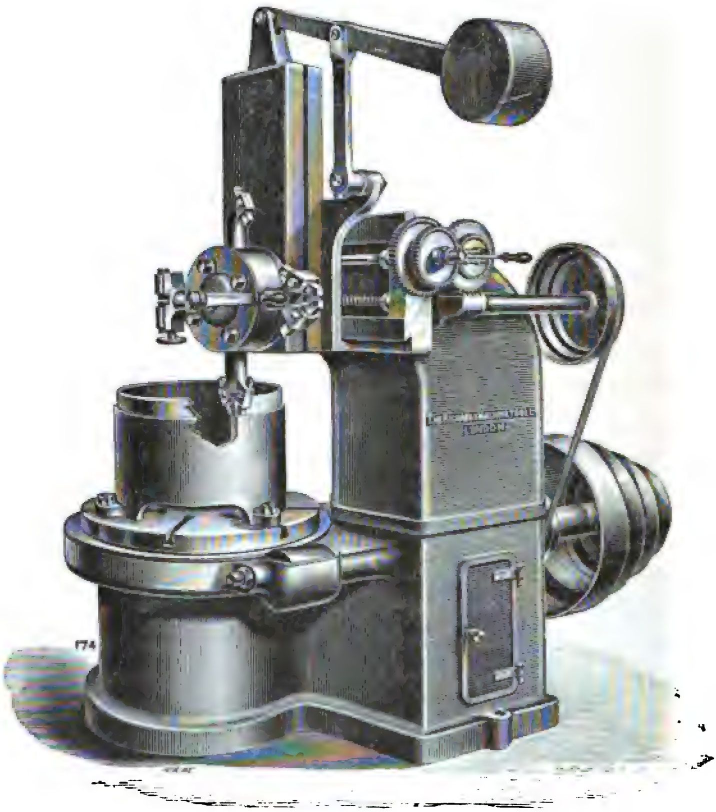
cially when the outlines are so irregular that the planing or slotting processes become difficult, and in some cases, impossible to carry out. In concluding our remarks, therefore, upon Milling Machines, we must note their special suitability for automatic copying work by means of a hardened steel plate, the edge of which is of exactly the same configuration as the detail to be shaped. Placed at one side of the machine table, a steel pin is made to bear against it in such a way as to control the lateral movements of the cutter, until the coupling rod, or whatever it may be, is accurately outlined.

Amongst the most useful of modern innovations is the *Universal Turning Machine*, one of which is adjacently shown. Here, the necessary tools are placed in position for manipulating work by successive stages on a horizontal table, thus saving a large amount of time, not only in operation, but in setting the work at the outset. This, in large machines especially, will be fully apparent when the great difficulty of fixing perhaps a five-ton casting on the vertical 15 or 20 feet face plate of a lathe is considered. Still more will this be the case when it is remembered that the tendency of the load is to disrupt its bolt fixings before any strain is thrown upon it from the cutting tools, and, if of irregular shape, to necessitate the application of heavy and most inconvenient back balance weights for steadying purposes.

So useful is the above type of machine that it has now become very popular, and is sometimes made of colossal dimensions under the title of *Circular Planing Machine*, on the table of which enormous castings can be set with great ease, their own weight helping to secure them in position.

The machine illustrated was designed for turning locomotive piston rings, but it is also used for many other

purposes, including the turning and facing of cylinder covers, machine cones, small fly wheels, etc., for which special and accurate table fixing appliances are provided. The table, of 26″ diameter, is driven by a worm and worm



UNIVERSAL TURNING MACHINE.

wheel, both of which are thoroughly protected from dirt, and well lubricated by being placed in a bath of oil capable of easy examination. On this table is fixed, for example, a cylindrical casting which is deep enough to allow several

rings to be cut from it when once set. The framing of the machine has both a transverse and a vertical slide, the feed of the former being 12″, and that of the latter 15″, the source of rapid operation, however, lies in the turret tool box, which carries four tool holders capable of being securely locked in any position.

The tools are capable of great variety, but are in each case exactly suited to the work they have to perform in rotation. That is, one single tool trues up the top edge of the casting, and another, of duplex nature, roughly turns down its inside and outside at one time, as shown in the view. No. 3 similarly finishes the ring to the exact diameters, and tool No. 4, also duplex, and very thin, does the cutting off part of the business, the operations at once recommencing in the same order for the next ring, and so on to the end, when a fresh casting is put on the table.

The above remarks apply more or less to the larger machines having a standard on each side of the table, with cross slide on which swivelling and otherwise adjustable tool bars are fitted to admit of duplex boring or turning. These machines, variously arranged, are now made in sizes, of which the largest is the colossal machine by Sir Joseph Whitworth & Co., for planing armour clad turrets, roller paths, etc., the table of which is 28′ 6″ diameter, and the slides so fitted with four reversing tool boxes that segments of circles can be operated upon in almost continuous fashion, and complete circles 35 feet diameter turned as in the lathe.

Two, at least, of the numerous secrets of financial prosperity in all engineering undertakings lie in the employment of the most suitable machinery for performing the required work, and also in the due apportioning of the skilled and unskilled operations with the object of avoiding

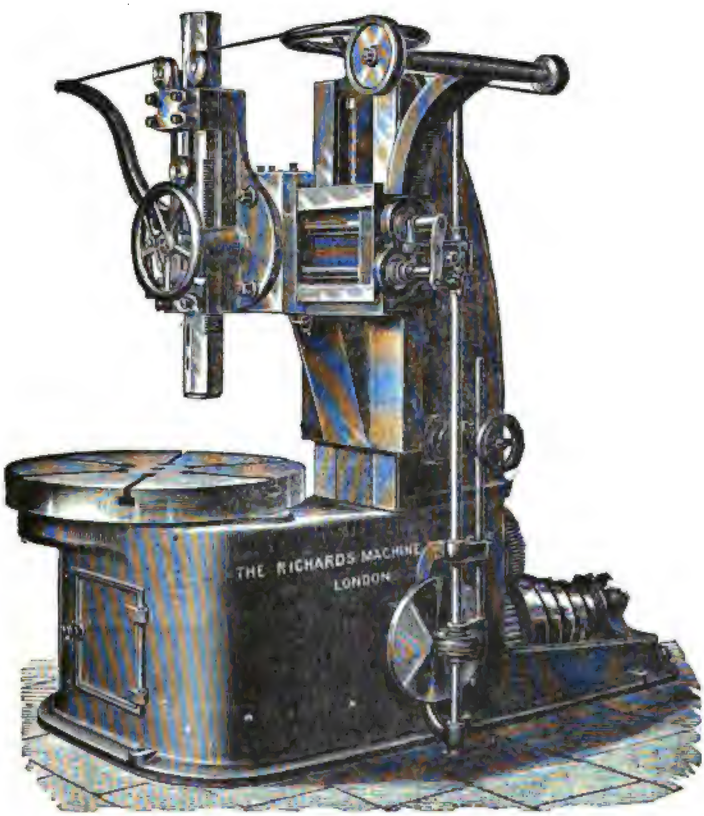
expensive labour, when that of a cheaper class may be successfully adopted. For instance, the usual practice at one time was to secure railway wagon wheels upon their axles by means of *keys*, now, however, this is not considered necessary. The smooth boring of the bosses for the reception of the axles, and the equally finished turning of the latter, were considered indispensable, but at present the latter are only rough turned to the proper diameter, and made to acquire a glassy surface and very tight fit by being hydraulically pressed into position in the wheel.

Then, again, so truly are the insides and outsides of wagon tyres now made in the rolling mills, that without any boring whatever, except at the clip rings, they can be shrunk on the wheel rims with sufficient accuracy, and if the tyres are exact enough in diameter at the tread, no external turning is needed, thus, not only leaving for wear and tear on the line the very hard outer skin of the metal, but avoiding at the same time the cutting in the lathe of such refractory material.

Where immense numbers of wheels of nearly the same size are made and repaired, as at the Earlestown Works of the London and North Western Company, all this means considerable saving in manufacture, owing to the nature of the traffic for which the above are intended, and which differs greatly from that of the passenger trains, where the highest class of workmanship is absolutely necessary.

Another method of economising skilled labour is to be found at Crewe, where multitudes of spring link, and other pins, not needing a Whitworth fit, nevertheless require a good fit. These, rough-turned very nearly to the size, are then passed by a boy between parallel cutters, fixed as in a die stock to the table of a drilling machine, which automatically finishes the work with interchangeable accuracy.

As in America, the system of boring and turning tyres in a vertical machine, instead of the lathe, is now immensely popular on account of its economy, we give adjacently a view of one of these which explains itself.



VERTICAL BORING AND TURNING MACHINE.

This machine will operate upon tyres up to 40″ diameter, the latter being fixed securely to the table, whilst the boring bar cutters execute the work. Machines of this

type, with either single or double standards, are now made for various purposes for work up to 30′ 0″ diameter, with great advantage to those who use them.

The most popular, and also the most suitable of all connecting rods for a locomotive, are those of the time-honoured butt and strap description, which at the crank end are unusually deep. For ordinary work the vertical *Slot Drilling Machine* described on page 117 has proved invaluable, but with the object of more rapidly operating upon the above and similar details in large quantities, the Crewe establishment has recently been supplied with a very admirable *Horizontal Duplex Slot Drilling Machine.*

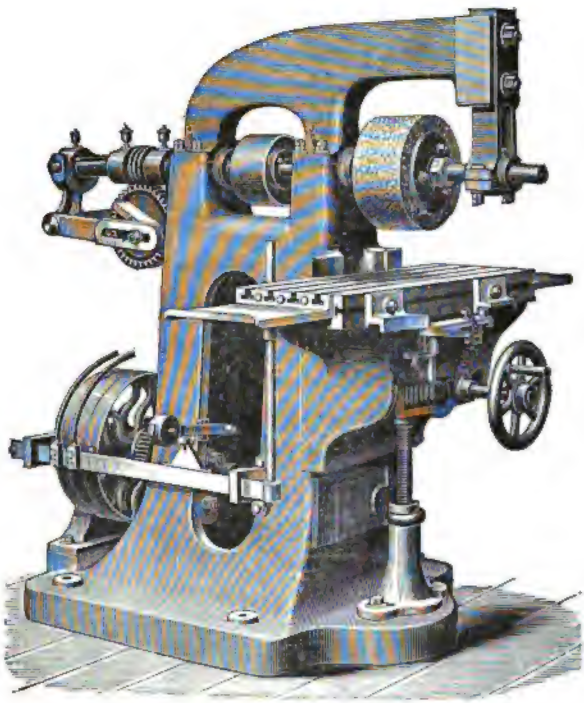
When in operation, four cutters act simultaneously upon both sides of the rod until they automatically meet in the middle, if required, when the machine stops of its own accord. It may be added that the cutter heads can either be used separately on short details, or unitedly on long ones, as they are capable of longitudinal adjustment along the bed as well as in transverse traverse at any point.

Advanced modern practice has caused the introduction of many special machines that formerly were unknown, those, too, which can alone allow progress to be made on certain lines. The original grindstone, primitively simple as it is, has not been found sufficient for many purposes beyond the rank of mere tool grinding, and often not even for that. Hence all sorts of *Emery Grinding Machines* have been introduced which perform their own class of work with rapidity and accuracy combined.

Many details exposed to much wear are case hardened to make them last as long as possible; with locomotive piston rod slide bars, therefore, it becomes necessary to true up their extremely hard surfaces by grinding.

Our adjacent view gives an example of a very useful

Crewe machine made for this purpose by Messrs. Luke & Spencer. The table is adjustable and traversable in the usual way, while the emery disc has a reciprocating motion given to it by gearing placed at the back. Hence it follows, that a slide bar thus operated upon has the required finish rapidly imparted to it.



SLIDE-BAR EMERY GRINDING MACHINE.

For innumerable other purposes of a less exact nature, much simpler machines are employed with great effect, especially is this the case when a light, but inexpensive, finish has to be given to castings, by simply grinding off

the steely outer skin of the metal that is otherwise so difficult to remove previous to burnishing. Emery wheels of this class are made to suit different kinds of work, and are extremely useful in surfacing castings that may be too thin or too hard for turning.

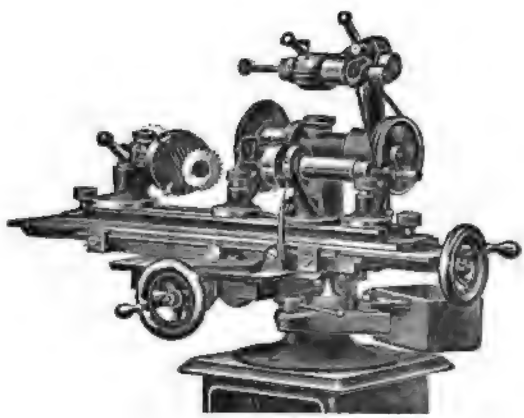
As a large amount of small brass castings that cannot be turned are highly polished, it has now become necessary to employ some more rapid and efficient method than that of filing. In view of this, the above firm manufacture a variety of machines, all of which are advantageously used upon suitable hand-operated work, the grinding and polishing discs being either of consolidated emery, or leather, or of any other description that may be required. We may only add that these wheels are now made up to 36" diameter, and from $\frac{1}{8}$" to 8" in thickness.

The excellence of workmanship produced by tools of all kinds being due to the perfection of their cutting edges, it is necessary to employ the most improved methods of preparing them. There are many very useful machines now made for this pupose, but one of the most extraordinary for general application is by the Norton Emery Wheel Co., of Worcester, U.S.A., the working-head of which is shown on the next page. For internal grinding of bearings, etc., the diameters of the emery wheels range from $\frac{7}{16}$" to $1\frac{5}{8}$", and for tool sharpening up to 7" diameter, the shape being made to suit the work. The circumferential velocities are 4,000, 5,000, and 6,000 feet per minute, that of 5,000 being usually employed in ordinary practice.

The machine has all its parts so designed that the various operations can be performed with them when arranged to suit. Revolving and other work up to 16" in length and $5\frac{1}{2}$" diameter, can be taken between the

centres, the sliding traverse being 10″, and the feed motion either automatic or otherwise as required.

Amongst the additional parts may be mentioned a vertically adjustable belt-slackening or tightening four-speed drum, and five-speed friction countershaft apparatus. The leading features of the latter are its compactness, and an arrangement which, by means of flat faced pulleys, enables the speed adjustable friction belt to be easily regulated, the cones being made to bite it by lever pressure. It may be noted that the machine is shown in



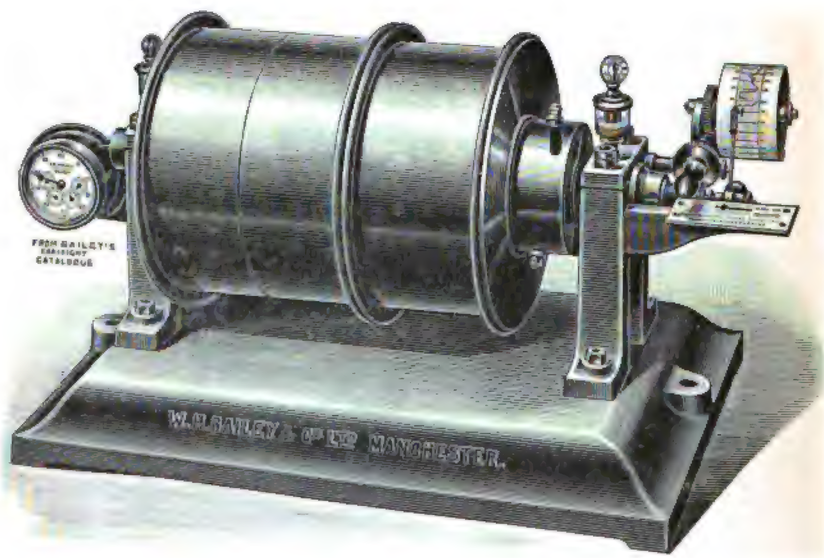
UNIVERSAL EMERY GRINDING MACHINE.

gear for internally grinding a milling cutter, the spindle and little emery wheel being swung upwards to allow of the application of the gauge.

The framing, of which the top only is seen, is of box pattern, and forms an excellent and convenient receptacle for all the wheels and tools in use, a hinged door enclosing them in the usual way. Besides this, the framing is made high enough to enable the machine to be conveniently worked, whilst its lower part is parabolically splayed out to

give the required rigidity under all circumstances. This system, now employed in innumerable constructions, has much to commend it, as it combines utility, elegance, and strength most efficiently.

As it is useful to have some means of visibly expressing the fluctuating horse power of machinery, we give a view of an *Improved Morin's Recording Dynamometer*, which well answers its purpose. The dial plate on the left indicates



IMPROVED MORIN'S RECORDING DYNAMOMETER.

the number of revolutions per minute of the belt pulley, whilst the drum on the right carries the indicator card, which can be removed when the registering pointer has done its work.

The card is divided throughout its length by transverse lines from zero to 2,500 revolutions per minute, and longitudinally by other lines from zero to 350 foot pounds per

revolution of belt pulley, the diagram, when completed, showing clearly the varying energy given out by the machine, after multiplying the revolutions per minute by the foot pounds, and dividing by 33,000, which will give the required horse power.

In all our remarks upon Constructive machines, we have referred only to those of the best description, and from the most authoritative sources of manufacture and application. It is not, however, too much to say that were it not for the excellence of the *Tools* supplied to them, their own usefulness would at once become neutralised. These tools should not only be of suitable steel and of correct formation for cutting purposes, but they must, in many cases, be rigidly kept true to gauge, otherwise great confusion would result. With turning, planing, and slotting tools, the latter qualification is not generally of much consequence, as accuracy of workmanship is entirely dependent upon the skill of the workman. With all kinds of drilled holes, on the other hand, requiring exactness, any irregularities that may exist in gauge dimensions are utterly inadmissible, and to prevent such evils, *Rhymers* are employed which true up with glassy finish and precise diameter the holes upon which they are brought to bear.

The ordinary rhymers need no comment as they are so well known; a special arrangement, however, is now employed, which provides a means of rectification when worn, so that the standard gauge can always be maintained.

"Taps and dies," "rhymers," "drills," "gauges," "mandrils," and so on, were quite household words amongst us in 'prentice days, and we, who used them so often, had every reason to appreciate their value as foundation tools, upon which indeed, as at present, the whole

fabric of mechanical engineering may be said to rest. In those days, Mr. Whitworth's screwing taps were amongst the most bèautiful of his minor productions, but what so often amazed us was the extraordinary amount of severe usage to which they could be exposed without showing signs of wear. This, however, was due to their exquisite temper, the secret of which was jealously guarded. It is the same process, too, to which our standard tools are still subjected, and which makes them marvellous specimens of the steel tempering art, without which constant and expensive renewals would become a necessity.

A machine tap is so tapered, and made of extra length, that it completes a screw in a nut at one operation; the others being specially applicable to holes closed at one end, and therefore only workable by stages.

Pipe screwing taps from 1″ to 3″ diameter have 11 threads per inch of length; whereas the others change from 20 threads for $\frac{1}{4}$″ diameter, to 8 for 1″, and $4\frac{1}{2}$ for 2″ diameter. Although the threads of bolts are made strong enough to withstand the severe shearing strain thrown upon them in practice, pipe threads are made much finer, as they are used only for jointing purposes.

When Mr. Morse invented the drill that bears his name he made a very distinct advance in practical science, an advance too, which has proved universally beneficial. These drills are made out of bar steel turned and ground to gauge diameter, and then spirally grooved by a milling cutter. In cases of emergency, any drill can be made to bore a hole slightly larger thán its own diameter by simply grinding its point a little to one side, the possibility of this occurring when not wanted being prevented in the above by a centre line, which acts as a guide to the grinder. For deep holes the action of these tools is so true that in all

cases where mathematical precision is not necessary the use of the rhymer may be dispensed with.

Another tool of universal application is the *Lathe Mandril*, which so conveniently enables a great deal of special turned work to be executed. Until the present system was introduced, this appliance was very faulty, now, however, we have an excellent *Standard Mandril*, by means of which the highest accuracy is insured, since, if anything is bored too small or too large, it will not fit the above, and so the mistake is at once discovered.

This mandrel is made of hard steel, the ends being carefully centred, and the body ground to the required gauge in the middle, the ends giving the largest and smallest sizes allowable for what is intended to be either a tight- or an easy-fitting detail, such, for instance, as fixed and loose pulleys on shafts. The diameters most in use for ordinary work range from $\frac{1}{2}''$ to $4\frac{1}{2}''$.

A most important feature of workshop economy is the application of *Measuring Machines* of great delicacy, as the foot rule is not sufficiently exact, although ordinarily very suitable and convenient for general purposes.

The principle upon which these machines are worked may be thus explained. If we suppose that a screw working in a nut has a pitch of *one fiftieth* of an inch, and if we also imagine that it has a hand wheel large enough to allow the rim to be clearly divided into 1000 parts, it follows that a traverse through one division against an index point must produce a movement of *one fifty-thousandth* of an inch, and so on. One *ten thousandth* of an inch, however, is for all practical purposes considered sufficient. So sensitive are these appliances that they will even indicate the amount of heat expansion of a piece of iron when held in the hand for a few moments.

In places where the utmost precision in workmanship on a large scale is required, the measurements are not by "eighths," and "sixteenths," and "thirty-seconds" of an inch, as given on the foot rule, but by decimals, the above measuring machine recording them with exactness.

Another point of vital importance in workshop economy is the skilful organisation of the *Tool Room*, where all the machine and hand tools, gauges of length and diameter, templets, etc., are kept in systematic order ready for use. Here, specimens of the most delicate classes of work are kept as standards of excellence, but in private establishments duplicates of the most finished examples of machined details are kept in the office for exhibition. This they most admirably fulfil, as enquirers after practical truth can thus have beautiful object lessons that may frequently influence them to become purchasers.

As it is necessary in the Crewe works to have complete and easy control of all the *outside* as well as the inside operations, lines of ordinary railway, some miles in length, traverse the area in every direction, and thus maintain a continuous connection with the main line. Besides these, there are about five miles of 18″ gauge line, worked by tiny locomotives which draw miniature trains, conveying materials and finished work from one part of the premises to another.

In addition to the nearly 7,000 men directly employed in the works, there are upwards of 700 engine drivers, firemen, cleaners and others at the *Steam Sheds* adjoining Crewe Station, who, although a detached colony, contribute in a marked degree to the continuously rapid despatch of trains, and also to the safe and economical working of all the company's lines, quite apart, however, from the minor centres of industry in other parts of the country.

Here, about 150 engines are daily kept under steam, for the comfortable housing of which suitable sheds, covering an area of nearly four acres, have been provided.

Much more might be added about these Works and their machinery, but enough has been said without unnecessarily entering into details, the object throughout having specially been to provide germs of thought for others to develop in practice similar to that which, at the magnificent establishment referred to, proved so attractive and instructive to the writer. This we have had forcibly brought before us owing to the fact that in these days of severe competition, a manufacture which is worked at a loss may be profitably carried on if the methods employed are of supreme excellence.

The phrase "made in Germany," which at one time caused so much discussion, was largely due to the very extensive employment by the Teutons of the highest resources of practical science. Through the efforts of those who officially investigated the cause of our commercial falling off in this respect, the discoveries thus made were so striking as to completely revolutionise our own Iron and Steel Manufactures by the installation of new plant of the most improved description, which, though involving an immense outlay, has nevertheless proved highly satisfactory to all concerned.

CHAPTER XX.

RAILWAY ROLLING STOCK.

Third Class Carriages of the "Sixties"—Midland Railway Innovations — Recent Improvements — American System and its Peculiarities—Ten Thousand Mile Run without Changing—Magnificence of the New English Carriages—Their Construction—Steam Stamping Operations—Duplex Cold Steel Sawing Machines—Hydraulic Multiple Punching Press—Six Spindle Timber Boring Machine—General Specification for Carriages—Wheel and Axle Manufacture—Construction of Mansel Wooden Wheels—Various Testing Operations—Automatic Brake Gear—London and North Western Carriage Working and Maintenance—Heating and Lighting of Carriages—Wagon Works at Earlestown.

HAVING taken a brief survey of the iron working operations at Crewe, we may now consider some of the peculiarities of *Railway Rolling Stock.* Those who have travelled in the third class carriages of thirty years ago will remember their cheerless aspect; their narrow spaced, uncomfortable seats; their miserable oil lamps, and their freezing temperature in winter. All these we have often experienced, and, therefore, can most feelingly appreciate the immense improvements which have been made during later times. Advances, too, which, in combination with very moderate fares, have raised railway travelling to its present exalted position,

Until within a recent period, there were invariably three classes of carriages, but in 1875 the Midland Company abolished the second class as it was so little patronised. The wisdom of this arrangement was considered by many authorities to be rather doubtful, either

from a financial or from a public convenience standpoint. The London and North Western were decidedly against it, and in this respect they were supported by the vast body of the railway experts throughout the country. Subsequently, however, a few of the leading companies adopted the system with excellent results, no doubt owing chiefly to the great improvements that had gradually been introduced into the third class cars, which have now made them all that people can reasonably desire. Notwithstanding this, the Midland have again three classes, namely, the Pullman car, and first and third; and the London and North Western *four* classes, or a special saloon in addition to the other three; thus providing dining, sleeping, drawing room, lavatory, and other accommodation for those who desire it. The great advantages of the saloon carriage are also extensively recognised by large pleasure parties, who, during the summer months, charter them for their private use at very moderate rates.

A still more recent improvement has been the adoption of "corridor" trains, having a free passage from end to end, and containing dining rooms for first and third class passengers, who are most admirably supplied with every comfort and convenience that modern ingenuity can devise. A few years ago, the Midland, in its anxiety to please everyone, set apart carriages for "ladies only," but their intended occupants persistently preferred the others.

In the United States, and in Canada, railway carriage luxury and splendour seem to have reached a climax. Here a passenger can seldom be more than eight hours on a journey, but on the vast continent of America the run may last from three to six days, hence something must be employed to compensate for a wearisome drive, by night and by day, over, perhaps, hundreds of miles at a stretch of

uninteresting prairie land. As the love of the beautiful exists in the minds of most people, our Transatlantic brethren not only provide extremely luxurious arrangements in their carriages, but also artistic embellishments which cannot fail to gratify even the most æsthetic.

As an example of the highest class of travelling perhaps in the world, let us take the New York Central and Hudson River Railway. This line has four sets of rails, two being for goods and two for passenger traffic exclusively, thus avoiding all risk of danger. Starting from New York, the main portion of the line runs due north to Albany, then westward to Buffalo, and, after embracing Lake Erie in scissor-like fashion, its two arms unite at Chicago, about 1000 miles distant from the starting point. The peculiarities of the line are: beautiful scenery, great luxury in travelling, and an extreme speed, which may be gathered from the fact that the distance of 436½ miles from New York to East Buffalo has been traversed in 439½ minutes, including all stoppages, and 425 minutes 44 seconds net running time, the speed having sometimes been at the rate of 75 miles an hour. On this occasion the train, as it stood, weighed 230 American tons of 2,000 pounds each, the engine having cylinders 19″ diameter and 24″ stroke, and driving wheels 6′ 6″ diameter.

The cars of these trains are from 60 to 70 feet in length, by 10 feet in width, and within these areas are included drawing-room, dining-room, sleeping, observation, private, buffet and café, and other accommodation. Bathrooms, lavatories, and all other sources of comfort are additionally supplied.

One of the main peculiarities of Transatlantic carriages is their fore and aft central gangway, a verandah platform at each extremity, and free passage from end to end of the

EXTERNAL VIEW OF DINING AND SLEEPING CAR.

train. As very much beautiful scenery is passed through an observation car is a great source of attraction, and is therefore fitted up as a little drawing-room. This is placed at the rear of the train, so that there may be no obstruction to the view, the sides and end being formed almost entirely of plate glass.

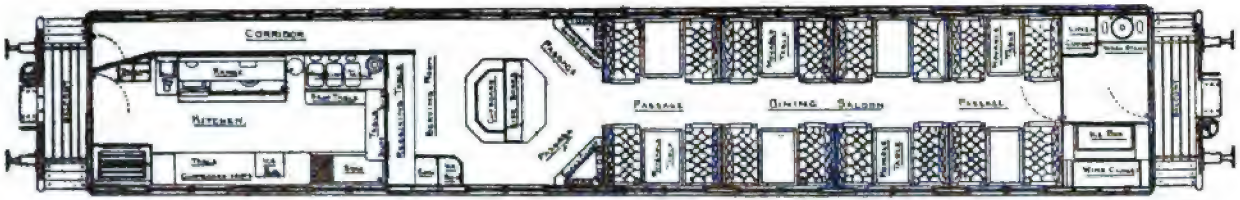
The annexed views of a *Dining and Sleeping Car*, made by the Lancaster Railway Carriage and Wagon Company for the Central Argentine Railway, will give a fair representa-

tion of those on American lines. The above is constructed to carry 26 night passengers and 45 day passengers, when fitted up as "sleepers," and to accommodate 32 persons when arranged as "diners." The length of body over platform is 66′ 0″; width of body, 10′ 6″; wheel base of bogies, 10′ 6″; and distance from centre to centre of the latter, 44′ 0″.

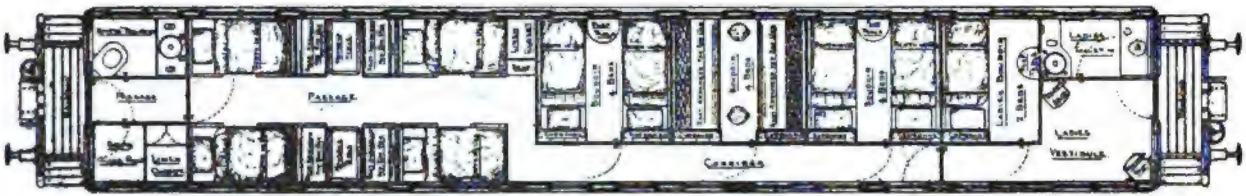
As a mere outside elevation of any structure gives very little conception of its internal arrangements, we show adjacently a *Sectional Plan of Dining Car*, and another similar view of a *Sleeping Car;* also on page 360 an *Interior view* of the latter.

This Car is used for ordinary passengers during the day, but, when bed-time arrives, the couches—whose bottoms now form part of the roof—are let down to a horizontal position ready for use. The seats are also adjustable, screens being put up between them when required.

The car of which the observation room forms a part has the same dimensions, and the same external appearance as that shown in our elevation, but is differently arranged inside. Sleeping accommodation is here provided for nine persons, including a private bedroom and dressing room fitted with two berths, wardrobe, writing table, cupboards, and lavatory. A luggage room and bath room, etc., are placed in the centre of the car, whilst at one end space is found for a kitchen and stove. With these facts in view, it will be seen that not only may one of these carriages become an hotel on wheels, but also a travelling residence of greater or lesser luxury, according to circumstances, for runs up to, say, 10,000 miles without changing. The interior of these cars is handsomely finished in oak and walnut, the chairs, seats, sofas, etc., are covered with red buffalo leather, and the floor laid with Brussels carpet.



SECTIONAL PLAN OF DINING CAR.



SECTIONAL PLAN OF SLEEPING CAR.

To return to the carriages employed on English railways, it may be said that the new ones are quite up to the requirements of the times, the absence of Transatlantic peculiarities being only due to the shortness of the runs, the garden island nature of the country, and the moderate temperature of the climate. From a *constructional* point of

INTERIOR VIEW OF SLEEPING CAR.

view, however, our carriages and wagons have quite as much care bestowed upon them as any other railway detail in any part of the world, since the safety of the train depends very greatly upon them. A forcible example of this is to be found in the accident that happened to an express train near Oxford many years ago, during a hard

frost, when the breakage of a four-wheeled carriage tyre caused the upset of the train, and the deaths and severe maiming of very many people. To avoid even the possibility of accidents happening from similar causes, carriage and wagon wheels, axles, etc., are now made to the most rigid specifications, and have their vital parts subjected to severe initial and final tests, six wheels are also used instead of four for obvious reasons.

So far as private works are concerned, those already mentioned are amongst the best, the machinery and appliances contained in them, and the system employed, fully enabling every operation to be conducted on the swift and precise lines of advanced modern practice. In this Lancaster establishment are manufactured every possible description of rolling stock, from the state carriage of a princess to the humblest timber wagon, the castings, forgings, stampings, etc., being made and finished on the premises by means of the usual machinery.

As the last-named process is so important, we give on next page an illustration of a very simple *Pillar Steam Stamping Hammer*, which has proved a useful labour saver.

This hammer is of the 10 cwt. size, to the upper surface of the massive bed plate of which the lower dies are attached, the upper dies being secured to the hammer face. The valve gear is so arranged that the latter rises to the top of its stroke as soon as the steam is admitted to the cylinder, and remains there until the hand lever is moved. It then delivers its blow with tremendous force, aided by the buffer spring against which the top end of the piston rod presses, and immediately rises to the top, as before, to be ready for the next blow.

The finished articles may consist of spanners, small crossheads, forked joints, ends of levers, handles, short

PILLAR STEAM STAMPING HAMMER.

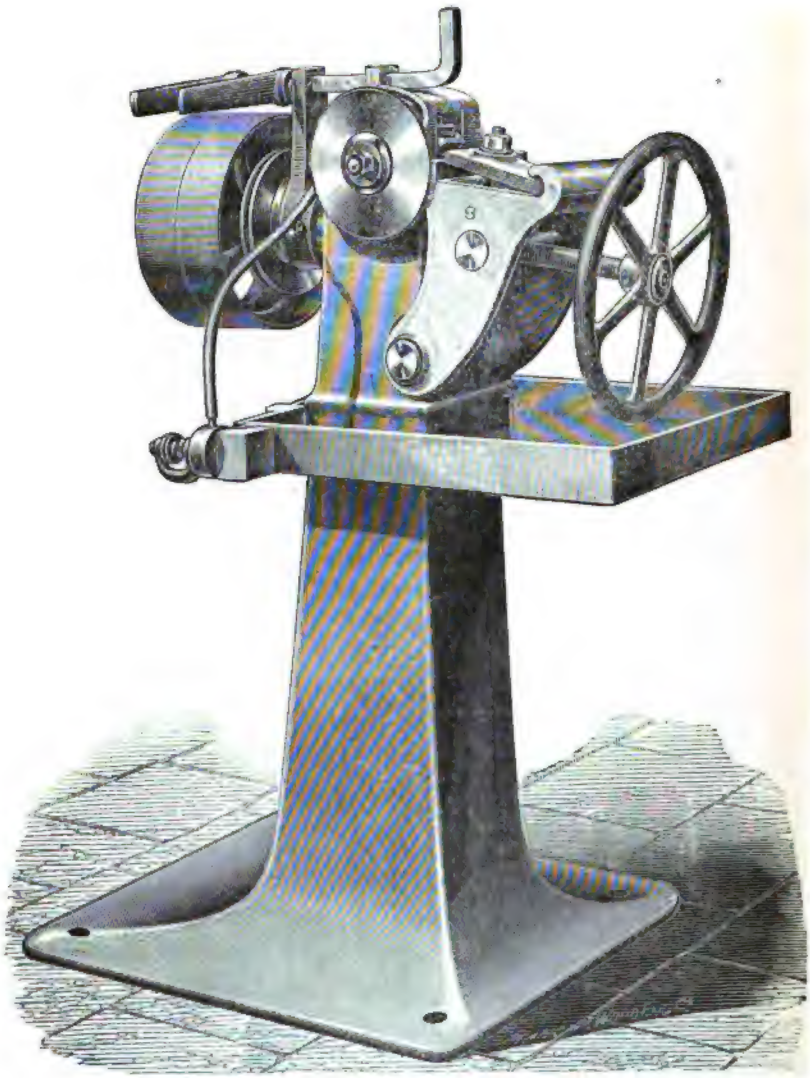
links, and many other more or less complicated details; should any of them, however, be difficult to disengage from the lower dies, the lever shown in the bed plate enables their instantaneous release to be effected.

As large numbers of wagons are now made with rolled channel steel framings, instead of wood, these have to be cut to gauge lengths by means of *Duplex Cold Steel Sawing Machines* that finish both ends at the same time, one of the headstocks being fixed, and the other longitudinally adjustable along the bed. A very important improvement in this respect, however, for both carriages and wagons, has been the extensive introduction of hydraulic-pressed channel frames, of any required shape, by the Leeds Forge Company, which have proved most serviceable.

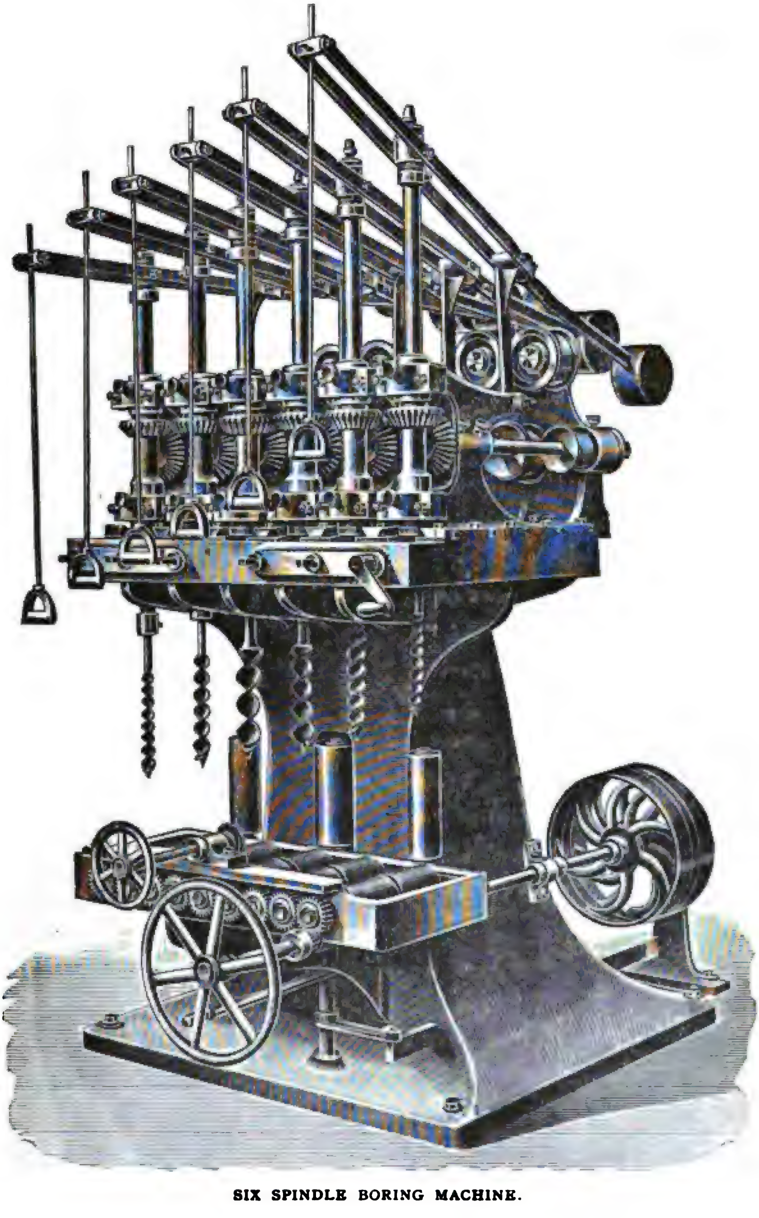
For cutting operations of an ordinary nature, on angle and tee irons, etc., the *Sawing Machine* by Messrs. Hetherington, shown on next page, is found most useful, the clamping, belt, lubricating and feed gear being under the immediate control of the attendant. This machine is usually in two sizes, one with a 10″ diameter saw for bars up to 1½″ square, the other with a 15″ saw for objects up to 3″ square.

In cases where many bolt and rivet holes are needed in one plate, a special *Hydraulic Punching Press* is employed, which enables a large number of them to be perforated at one stroke, and as all the punches are adjustable in position, complete interchangeability is attained at every point in any number of plates.

When timber framings, however, are employed, one of the most useful and recent types of labour-savers for railway carriage and wagon building is the *Six Spindle Boring Machine* by Messrs. Robinson, shown on page 365. It is of very strong construction, and is capable of



COLD STEEL SAWING MACHINE.



SIX SPINDLE BORING MACHINE.

operating on timber up to 16 inches square, and boring holes up to 3 inches diameter by 16 inches deep. The spindles are carried on independent headstocks, which are separately moveable in a lateral direction by means of screws, so that they can be set to bore holes in any required position without moving the timber after it is fixed on the table. The advantage of a machine having six spindles so easily adjustable is considerable, as it enables the various sized holes required in a wagon frame to be bored without losing time in changing the augers.

The table is fitted with geared rollers, which are revolved by a hand wheel, the timber to be bored while resting on these being thus quickly and easily moved in a longitudinal direction.

The *General Specification* to which carriages, wagons, wheels, axles, and miscellaneous iron work are made, also the painting, varnishing, marking, and packing of the same for export, depends in many cases upon the wishes of the Company for whom the vehicles are intended. When, however, this specification is not provided, the Lancaster Company use one of their own.

To give some idea of the manner in which carriages, wagons, etc., are thus constructed, it may be mentioned that the external body framing and panelling of the former are of East India teak, or of mahogany, strongly bound together with braces, tie rods, and iron knee brackets. The roof and floor boards are of red deal, or of teak for Indian work, the former being covered with strong canvas, painted, and thickly coated with white lead. The interiors of first class carriages are finished in wainscot oak and walnut, or in mahogany and ash, or sycamore, or bird's eye maple, the seats being covered with leather or woven cane, and the floor laid with linoleum. Exteriors may be

painted any approved colour, or left plain, but in either case they receive from six to twelve coats of varnish, the interiors being French polished. The under-frames, wheels, axles, etc., are oiled and painted black, so that they may not only be well preserved from the effects of the weather, but have at the same time a good serviceable finish.

As the safety of all carriages and wagons depends greatly upon the excellence of their wheels and axles, the utmost care is taken to ensure their absolute faultlessness during manufacture. The diameter of the former on the tread ranges only from 2′ 9″ to 3′ 7½″, but their construction varies greatly, the centres, for example, being of cast iron or cast steel, or of teak with cast iron bosses and steel face plates or wrought iron solid discs, or the wheels may be entirely of cast iron, or steel, according to circumstances. The most popular wheels for carriages, on account of their smooth running properties, are the well-known "Mansel," which are made without spokes, the centres being solidly formed out of segments of teak. Their usual method of manufacture is as follows:—

When the tyre has been suitably bored it is placed in a hydraulic press, the above segments—already cut and accurately shaped by an automatic machine in the wood working department—being placed in dished form within its circumference. The ram now descends, and with enormous force so squeezes them into position as to make the teak centre as compact as if it had been formed out of a solid piece of timber. Nothing more requires to be done than to fix the retaining ring and boss plates, hydraulically force the pair of wheels on their axle with a pressure of about 70 tons, and then key them in position ready for use.

When tyres and axles were made of iron, they often broke through constructional defects, but when steel was substituted for it failures arose out of inherent flaws in the metal. It therefore became necessary to compel the material of these details, as well as the finished work, to undergo tests similar to those given in Chapter IV. At the Lancaster Works many of the forgings are either stamped out of the solid under steam hammers, or drop stamps, and hydraulic press-welded or electrically welded when required, all the heating being performed in gas furnaces, thus securing the most perfect work and cleanest finish.

In past days one of the main causes of accidents to trains was the very imperfect speed-controlling appliances then in use, which often made it impossible to stop a train in time to avoid a serious collision. This dangerous feature of railway practice induced Mr. Westinghouse to invent the *Automatic Brake Gear* which bears his name, and which has long been very extensively employed in almost every country of the globe.

The brake is continuous throughout the train, and is operated by compressed air stored in a main reservoir on the engine, and in auxiliary reservoirs, of which one is placed upon the engine tender and every carriage, all being connected by a pipe running the whole length of the train. There are also on each vehicle a triple valve and a brake cylinder, having its piston connected to the brake levers, by means of which instantaneous action is insured, either when an accident occurs to any principal part, or in ordinary running.

As even great railway companies differ in their opinions, sometimes on the simplest matters, it may be well here to state that the whole of the stock of the

London and North-Western is supplied with the well-known *Automatic Vacuum Brake.* This brake is applied to all the carriages of a train, except the engine and tender, which are fitted with a separate steam arrangement, and as each vehicle carries its own length of train pipe, flexible hose, and universal couplings, etc., a train running at full speed can be brought to rest with great rapidity and without shock, the vacuum in this case producing results similar to those of the Westinghouse arrangement, but in a different manner.

So skilfully has this apparatus been designed that every carriage is brought under the immediate control of those in charge, and the disconnection of carriages with the least amount of trouble is fully provided for.

Apart altogether from the great works of the Company at Wolverton, the superintendent of the carriage department has under his control at outside stations a large number of men who are engaged in the examination, repair, greasing, lamping, washing, cleaning, and warming of the carriages throughout the system, so that everything may run in perfect order.

To enable the rigid *examination* of all the carriages to be satisfactorily conducted, skilled examiners are employed, who, singly or in small parties, are located at the most important stations and junctions throughout the system. These men must have considerable experience in the lifting and repairing of carriages in the shops, and in the survey of wheels, springs, and other working gear of all carriages passing through their stations, part of their duty being to test every wheel tyre with a hammer, so that if any flaw exists it may thus be detected before, perhaps, great mischief is done. Where no special staff is employed, the examiners have also to attend to slight repairs of

internal fittings, etc., the under gear being inspected at important stations.

Next to the examiners come the *greasers*, who are located at the principal stations, their duty being to inspect the axle boxes of all carriages passing through their district, and to replenish them with oil or grease when needed. By means of the two operations just referred to, it is now almost impossible for a tyre to give way when running, or the bearing of an axle to become dangerously heated by undue friction, as formerly was the case.

The operations that conduce to *cleanliness, beauty, and comfort*, are also of great importance, because they so closely affect the well being of the public, upon whom the financial success of a great line so much depends. Here again the London and North Western is well to the fore in all respects, every carriage being once a day carefully washed outside with water. This is obtained from iron tanks let into the ground, a self-acting apparatus enabling the buckets to be instantly filled. At the main stations there are sheds so arranged that a large number of carriages can be cleansed with great rapidity, platforms, troughs, etc., unitedly facilitating every movement to the utmost. In addition to these, the carriages receive a periodical scouring with some cleaning composition, the appliances required for the various operations being merely a bucket, a long-handled brush, and a small spoke brush for getting into corners, etc.

In the "good old days," when people were sometimes almost frozen during a long journey, they little dreamt of the comfort in store for them by means of foot warmers. As these, when filled with mere water, cooled down rapidly, the London and North Western introduced some time ago a special innovation of their own, which success-

fully overcame the difficulty by the application of specially prepared acetate of soda. The advantage of employing this still popular process arose from the fact that when a warmer cooled down, much of its original heat could be restored by *shaking* the receptacle, thus enabling it to last nearly three times as long as formerly, and avoiding inconvenience to passengers during a long night journey. The sleeping saloons and others on the above line, in the through trains between London and the north, are now warmed by means of high and low pressure hot water pipes, each saloon being supplied with a small heating apparatus for the purpose. The new West Coast Fast Service Corridor trains, and special coupled trains, however, are heated on the "Consolidated" system, by steam, at a reduced pressure from the engine.

On the line to which our remarks still refer, as well as upon all others, the old style of *lighting* the carriages with oil lamps has been superseded by the compressed oil gas system, which is greatly superior. This gas is manufactured from shale oil, and stored in reservoirs about 18 feet long and 4 feet diameter, built up of $\frac{1}{2}''$ plates, to stand a working pressure of 150 pounds per square inch. Each carriage has two steel plate cylinders filled with this gas to a pressure of 110 pounds per square inch attached to them, and these, when 16′ 0″ in length, by 13″ in diameter, will carry enough to keep 20 lights burning on a journey from London to Aberdeen and back. As, however, the gas cannot be consumed under such a high pressure—it is passed through a regulator, so that it may be reduced to the ordinary household standard.

This is effected by means of a very simple contrivance, which enables each jet to be of a given size, so that it cannot blaze and cause waste, all the lights in a carriage

being under complete control in the usual way by the aid of a key. Each carriage has also a gauge, which indicates the pressure of gas in the cylinders, and shows when the supply is exhausted. It may be added that the London and North-Western Company employ electric lighting in many of their carriages instead of gas.

Some idea of the enormous extent of the *Goods Traffic* of the above line may be gathered from the fact that in one year it amounts to about 37,500,000 tons, in the working of which upwards of 60,000 wagons are employed. Hence it follows that the *Wagon Building and Repairing Works* at Earlestown now cover an area of 35 acres, and employ about 1,600 men, notwithstanding the very liberal use of all the latest and best machinery of the day. Part of this, however, is caused by the employment of a fleet of 20 more or less magnificent steamers, which maintain a very heavy passenger and goods traffic between Ireland and Holyhead, where the Company possess a capacious harbour, fitted in the most complete manner with all modern buildings and appliances.

To enumerate the various kinds of wagons on a great railway would be quite unnecessary, as so many of them are to be seen in constant use.

CHAPTER XXI.

TUNNELLING OPERATIONS OF THE PRESENT.

Cuttings and Tunnels Compared—Forces of Nature as Excavators—Examples of Ancient Tunnelling—Effects of Changes of Strata—A Disastrous Example—Accuracy in Tunnelling—Advantages of Compressed Air Machinery—The Longest new Tunnel of the World—Picturesque Features of Tunnelling—Immense Difficulties of the London Underground Railway—Rock Drilling Machine—Its Efficiency and System of Action—Long Distance Compressed Air Transmission—Daw's Loss of Pressure Table—Air Compressing Motors—Compressed Air Storage—Tunnelling Operations Summarised—Improved System of Blasting.

WE left some time ago our good friends on the Deephaven and Bathurst railway works with everything progressing rapidly owing to the flat nature of the country. This, however, had now become changed into mountain and valley scenery, which required a certain amount of cutting, embanking, tunnelling, and bridging, the cost of which, though very considerable, would eventually be more than compensated for by the advantages they would confer upon the line.

The object of a tunnel is to avoid a perhaps very long and expensive round-about track, from which little benefit can be derived and which would load the railway ever afterwards with the interest of unnecessary first cost, and also heavy working expenses, both being objects that the skilful engineer avoids to the utmost. Sometimes, too, it becomes absolutely necessary to cut through a hill or a mountain because no other method is available, just, indeed, as it has now become on our Baratanian line.

"*Cutting*" consists in excavating an open passage of greater or lesser dimensions; the term "Tunnelling" being applied to the construction of an underground channel, the superincumbent covering of which remains untouched. If the above cutting is arched over near the bottom, and then filled in with the top soil, it becomes a "covered way." Making a small tunnel to be afterwards widened into a large one, is termed "driving a heading," but in mining operations this is styled a "gallery," "driftway," or "adit." If the same passages were cut *vertically*, instead of horizontally, they would then be called "shafts," and these, for general engineering purposes, such as mining, well-sinking, etc., may be of any dimensions to suit the end in view.

The forces of nature have had much more to do with tunnelling than some would imagine, many rivers having thus made a course for themselves under ground. The Peak caves of Derbyshire, and the Mammoth Cave of Kentucky being also examples on a large scale of the same operations. With so many natural examples before them, it is not surprising that some of the earliest works of the ancients were of this nature, firstly for dwellings and tombs, then for quarrying and mining, and lastly for water supply, drainage, etc., purposes. How these works were executed may be gathered from the fact that the tunnel, 12 feet high and 15 feet wide, under the Euphrates at Babylon, was dug out of soft ground by hand, and then arched with brick; while, as stated by Pliny, the tunnel constructed under Monte Salviano, for the drainage of Lake Fucino, was 10 feet high, by 6 feet in width, and 3½ miles in length. To enable the undertaking to be carried out, 40 shafts were sunk, some of which were 400 feet in depth, the services of 30,000 labourers being required for

eleven years. For hard stone, the tools employed were the hammer, chisel, tube drills, and saws supplied with corundum, etc., and water, which even at that period acted well though very slowly.

In districts of a hilly nature, where a railway of considerable length is to be constructed, it is frequently necessary to excavate a tunnel when the depth of the alternative cutting would be upwards of 60 feet, unless, indeed, the material is required for some adjacent embankment. Constructive economy generally is, however, the leading feature in the case, since with modern improved machinery, rock excavations of any required length are easily accomplished.

Rocky strata of a freely workable nature are usually the cheapest for tunnelling, owing to the absence of the lining necessary in other cases, and to the saving of labour by the use of gunpowder. Clay, on the other hand, is sometimes expensive to work, as it is, when tough, very difficult to remove, and blasting is of no use. Tunnels formed through chalk are often impeded by cavities filled with wet sand or gravel, which pour a flood of semi-fluid matter into the excavations as soon as they are cut into. In all cases, however, a safe, but not always infallible precaution consists in carefully examining the ground by means of trial borings, so that sudden breaks or faults in the strata may be discovered at the outset.

A very remarkable and unexpected change of strata occurred during the excavation of the Kilsby tunnel, on the old London and Birmingham line, which was one of the earliest and most difficult undertakings of this nature. The hill through which it passed had been tested by trial shafts and found to consist of oolitic shale, and upon this, as a basis, the work was handed over to the contractor. Unfortunately, it was afterwards discovered that between

the shafts, under a bed of clay 40 feet thick, there existed a quicksand, which, when pierced, discharged an immense volume of water. Through the prolonged efforts of the contractor to execute his undertaking satisfactorily, the original estimate of cost rose from £99,000 to about £300,000, or £125 per lineal yard, and this so overwhelmed the poor man that he soon afterwards died.

Amongst the most celebrated modern tunnels of the world are those of Mount Cenis and St. Gothard, not only on account of their length and importance as engineering schemes, but owing to the flinty nature of the rock through which they passed, and which caused the introduction of a mechanical process which has since been much improved. The first named tunnel of 7½ miles in length was begun in 1857, and opened for traffic in 1871, at a cost of £393,600 per mile, or £223 per yard, the excavations having been made in lime-stone. During the first four years of construction hand labour was employed, the average progress being at the rate of nine inches per day, but when compressed air rock-drilling machinery was introduced this was increased to at least 3′ 9″ per day.

The St. Gothard Tunnels are a still more magnificent and difficult specimen of engineering, as they were in some places of the helicoidal or cork-screw formation, with steep gradients, the average radius being 15 chains. The main tunnel of 9¼ miles in length was commenced in 1871, and finished in 1881, at a cost of £143 per yard, the excavations having chiefly been made in gneiss granite.

It may be asked how tunnels such as the above can be excavated from two sides of a great mountain several miles apart and yet be made to meet with precision at the centre? The answer is a simple one. It all depends upon the extreme accuracy of the means employed by the

engineers and the trustworthy nature of their instruments, without which very serious errors would be made. The methods employed have been fully described in various treatises, and therefore need not here be referred to, but, difficult as the process may appear to many, it is simple enough when one comes to know it.

The great success from every point of view of the St. Gothard undertaking has resulted in recent large extensions, the average cost of which was only £85 per yard. This, however, has not been accomplished through easier geological conditions, but by the use of greatly improved machinery for boring and ventilating, and of other appliances which have considerably lessened manual labour.

It was a happy idea that brought about the introduction of compressed air apparatus to these works, not merely from a mechanical point of view, but from the atmospherical standpoint, which was, at one time, a very serious difficulty. This will be apparent when it is considered that the main obstacle to be overcome was the badness of the air, which became worse as the mountain was penetrated. Besides this, the blasting process produced large quantities of foul atmosphere which hung in the workings. By the above machinery, however, pure air was conveyed in sufficient quantities to sustain the workmen, who previously had been greatly inconvenienced and delayed in their labours.

Although the tunnels just mentioned are things of the past, they nevertheless pointed the way to future advances in this direction. Advances, too, which have so raised the art of piercing vast mountains and submarine burrowing to their present exalted position, that nothing seems too great for the resources of the engineer. Recent events fully confirm this, one of the greatest of

undertakings now in progress being the Simplon Twin Tunnel, which is to be fully 12 miles long, and to consist of two parallel excavations, each for a single line, 56 feet apart. Five different cross sections are to be adopted to suit the nature of the ground, and these will be the means of ensuring economy and efficiency at all points.

The picturesquely striking features of tunnel-making must be witnessed to be fully realised. The visitor may perhaps be standing at a point where, several hundreds of feet below the surface of a mountain, the lamps of the workmen; the weird like lights and shades of the scene; the machinery employed; the heterogeneous collection of rubbish lying about; the noise of blasting; the crash of solid material falling to pieces; the reverberations of these startling sounds throughout the caverns thus created; and the varied surroundings and experiences combine to produce an effect which may daunt people who are not sufficiently prepared for what they are going to see and hear, not to mention a certain amount of risk to those who do not know how to avoid it when once in.

The most extraordinary operations of this nature in England were those connected with the Underground Railway in London, where, for very many miles, a series of tunnels had to be cut under, over, and through a vast network of gas and water pipes, sewers, etc., and at the same time avoid accidents to the valuable property just above them. The difficulties thus encountered are almost beyond belief, but the undertaking throughout has been a prosperous as well as an indispensable one.

After what we have said thus far upon the subject, it may be well to explain the nature of the appliance which has made rock excavation of all kinds a comparatively easy art. In purely mechanical engineering, several

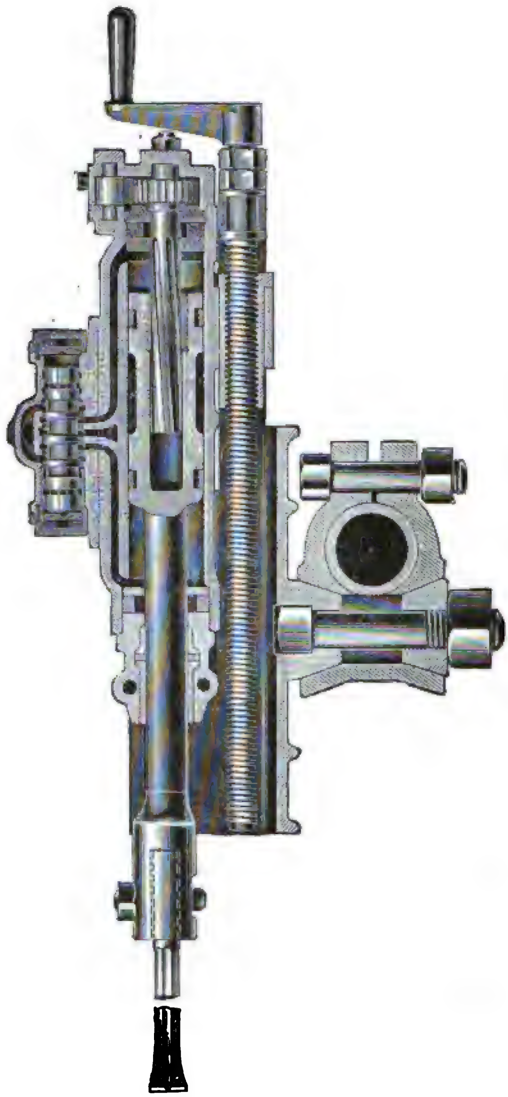
machines are frequently employed in certain progressive operations, but in the mountain piercing of the present, and perhaps the sea bed tunnelling of the future, the *Rock Drilling Machine* must be the only one which can enable the work to be successfully carried out.

This machine, by different makers, and in various forms, is now well known to the railway and mining world, here, however, we shall only refer to one by Messrs. A. & Z. Daw, which contains some of the most recent improvements, and is capable of drilling holes up to 3½" diameter in the hardest rock.

Firstly, we may remark, that, like all others of its class, it owes its penetrating power to a percussive and partially revolving action of the tool at each stroke, and to show clearly the manner in which these combined movements are executed, we give in the illustration on next page a sectional view of the working barrel.

The apparatus mainly consists of a piston rod and piston, which are caused to reciprocate by means of high-pressed air admitted by the cylindrical valve shown in the view. The encumbrances that once existed in this part of the gear have been so dispensed with that the result is a drill of great simplicity and good wearing power, and so short as to enable it to work in positions formerly inaccessible. It can also be placed so as to take advantage of every wall and cleavage, whereby greater progress can be made, and a large saving in explosives effected. The valve thus designed is capable of working with the greatest ease and certainty, and with steam as well as with compressed air.

The piston is so fitted as to maintain its full efficiency for a long period, and the twist gear is formed of special steel so that it may have the greatest endurance, a small



SECTION OF ROCK DRILLING MACHINE.

ratchet and wheel enabling the necessary twist of the drill spindle to be accomplished at the end of each stroke.

The handle and screw are not only used for feeding purposes, but for regulating the position of the drill to suit the work upon which it has to operate, and the bar clamping gear, as shown, is designed to enable the apparatus to swivel in any required direction before being immovably locked.

The borers themselves are so important that without suitability on their part, the machine, however perfect otherwise, would be of little use. They are therefore made of carefully selected steel, and the ends are + shaped, as in the above view, for some kinds of work. In gneiss, and homogeneous rocks, free from faults, the ordinary –, or chisel shaped end is the best, as it cuts faster than the others, and is more easily smithed when damaged. In schistose rocks, however, with layers of uneven hardness and numerous fissures, + or × pointed drills should be used instead of the latter, as those of chisel formation get out of line, jam in the fissures, and throw unnecessarily severe strains upon the machine.

The drill shanks, according to the size of hole to be bored, are made from 1″ to 1½″ diameter, the boring part being made to suit holes 2½″ to 4″ diameter, their depth in the largest sizes reaching about 20 feet. When the holes to be bored are beyond the travel of the machine, the original short drill is replaced by longer ones in succession until the required depth is attained, a stream of water being used to clear the apertures of chippings.

The machines are made in various sizes, their air cylinders usually ranging from 2½″ to 4″ in diameter, and their power for boring purposes may be gathered from the fact that, at 60 lbs pressure per square inch on the

TABLE SHOWING LOSS IN PRESSURE DUE TO THE FRICTION OF COMPRESSED AIR IN STRAIGHT PIPES.

Diameter of Pipe in inches.	Air compressed to a guage pressure of lbs. per square inch.	Cubic Feet of Compressed Air passing through Pipe per minute.																		
		10	15	20	30	40	50	60	80	100	120	140	160	180	200	250	300	350	400	500
		Loss of Pressure in lbs. per square inch for each 1,000 feet of straight Pipe.																		
1	60	11.71	26.34																	
1¼	60	3.84	8.83	15.34																
1½	60	1.54	3.47	6.17	13.88															
2	60	.37	.82	1.46	3.28	5.85	9.15													
2½	60	.12	.27	.48	1.08	1.92	3.00	4.32	7.68	12.00										
3	60		.11	.20	.43	.77	1.20	1.74	3.08	4.82	6.94	9.44								
3½	60			.09	.20	.36	.56	.80	1.43	2.23	3.21	4.37	5.71	7.22						
4	60					.18	.29	.41	.73	1.14	1.65	2.24	2.93	3.70	4.57	7.15	10.30			
5	60						.10	.13	.24	.37	.54	.73	.96	1.21	1.50	2.34	3.37	4.60	6.00	9.37
6	60								.10	.15	.22	.30	.39	.48	.60	.94	1.35	1.84	2.41	3.84

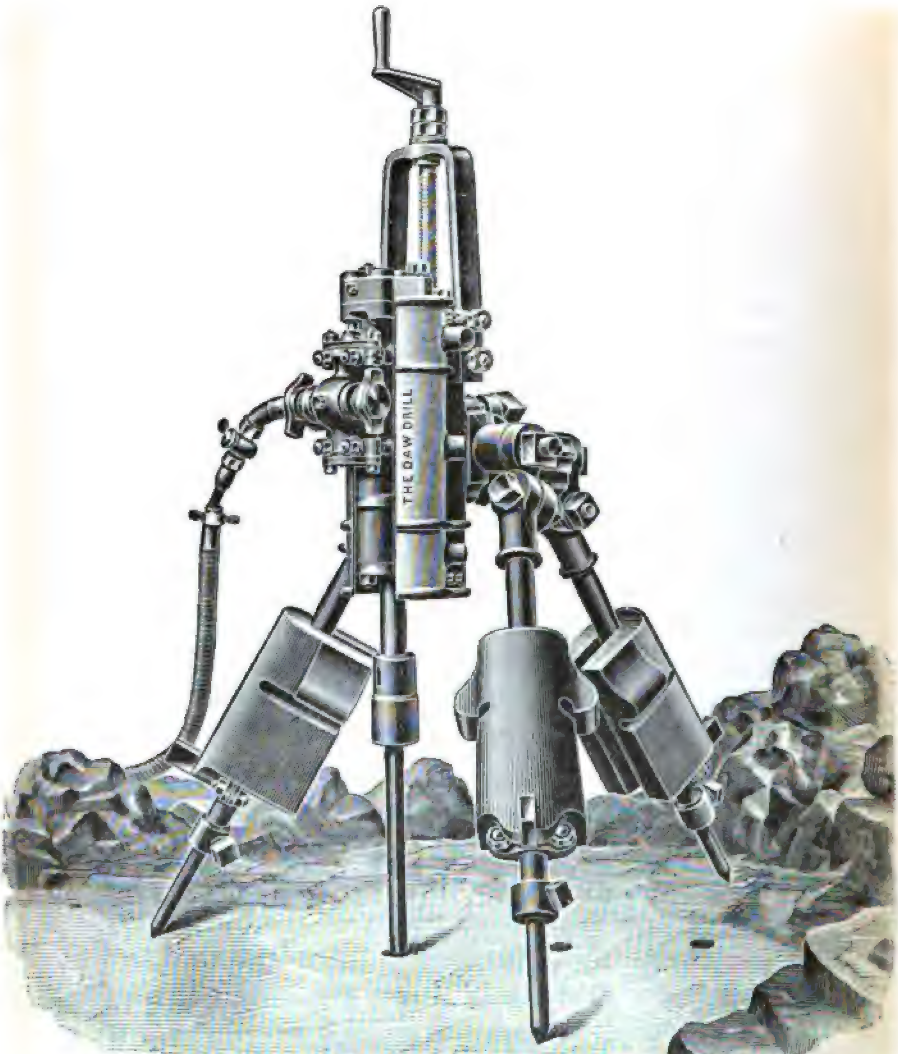
piston, a 3″ cylinder drill will deliver from 700 to 800 blows, each of 175 foot pounds, per minute.

For pipes up to 5″ diameter, wrought iron is usually employed, the screwed connections for each length being the same as for ordinary water or steam tubes, which are of a very convenient nature and capable of easy extension as the work proceeds. A great advantage possessed by air transmission in this manner over long distances, when compared with steam, is the extremely small loss of pressure sustained in transit, clearly visible by the annexed abridged Table taken from one by Messrs. A. & Z. Daw, which will be useful for other purposes.

The above table only refers to *straight* pipes, because these alone ought to be used when possible, as bends and angles add greatly to the friction of the air, and consequently decrease the pressure at the point of delivery. To allow, however, for rapid adjustment of the drill in any position, from 25 to 50 feet of flexible steel armoured hose pipes are supplied to each, which, with their attachments, are shown in the two following views.

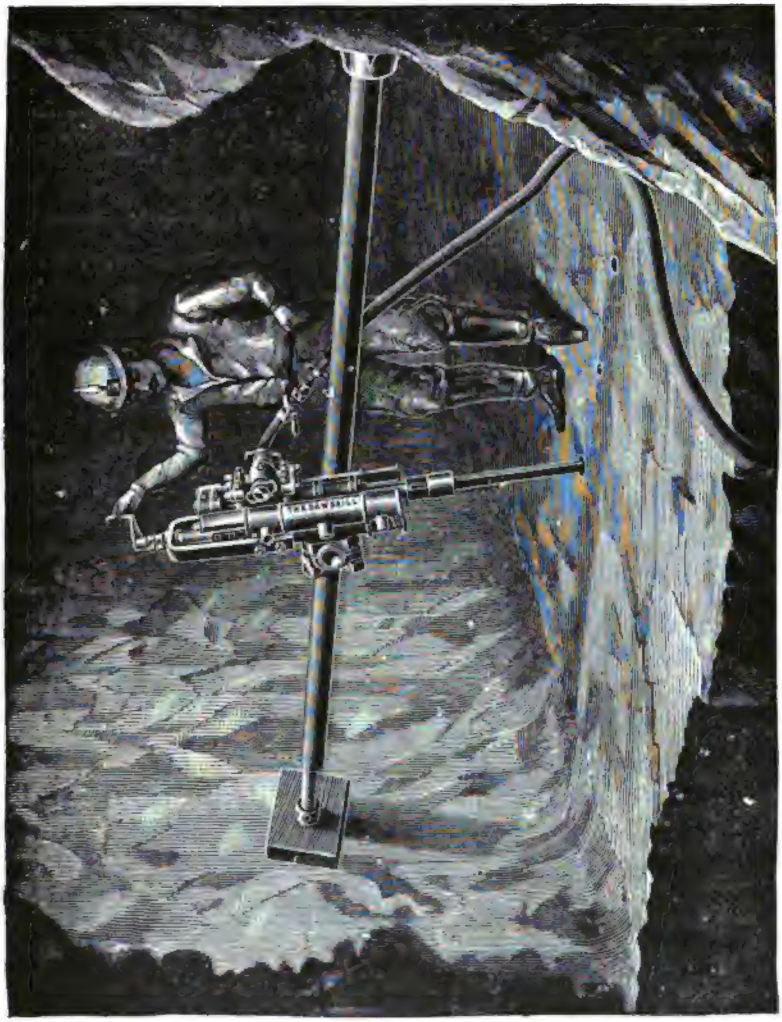
The first of these is an illustration of a 3½″ *Cylinder Drill*, mounted on an adjustable tripod, for excavating in quarries, railway cuttings, shafts, and open work generally. Universal adjustment is given to the three legs, which are also made telescopic, so that the tripod can be fixed in any position on the most irregular ground, and with perfect steadiness, the drill being adjusted to bore holes in any direction from vertical to horizontal. The tripod combines strength with rigidity and lightness, as well as portability and simplicity, the anchoring weights being capable of alteration in position or removal when necessary.

A method of applying the machine for tunnelling purposes is given in the plate on page 385. Here, a driftway



TRIPOD ROCK DRILLING MACHINE.

has been made, at the bottom of which holes are being bored so that a portion of the rock may be blasted off,



ROCK DRILLING APPARATUS IN TUNNEL.

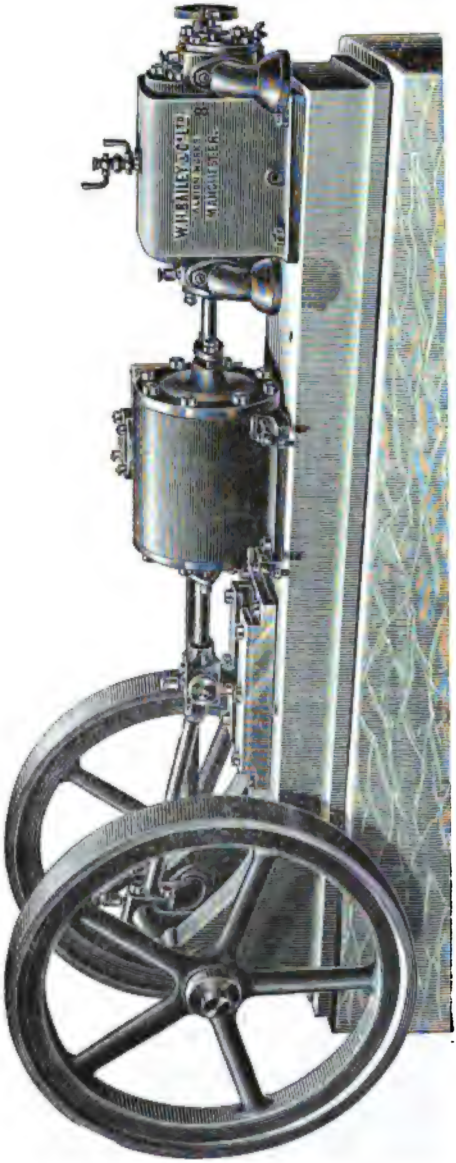
their diameter, distance apart, and depth, being regulated by the peculiarities of the case. It will be noted, how-

ever, that although the machine and its connections are the same as in the last example, its method of fixing is entirely different. Here, a horizontal tubular bar is used which is capable of screw adjustment at the end, so that all inequalities of the rocky sides can be taken advantage of by the use of timber packing as shown, or otherwise, the whole apparatus being thus easily applied at any point, and in any position, as the work proceeds.

For *Air Compressing* purposes, machinery of various kinds is employed which may be worked either by water power, or by steam power, or by electricity, according to circumstances, the first named being often usefully available when the required energy can be developed by means of a wheel or a turbine. Notable examples of this have been found in the works of the Mount Cenis, St. Gothard, Hoosac, and other tunnels, where power has been transmitted from two to four miles by means of compressed air. In hilly countries having an abundant rain fall, much energy is lost which might easily enough be utilised, and it was this thought that caused Lord Armstrong, whilst one day casually observing some mountain streams in Yorkshire, to conceive the happy idea of employing water power in machinery. This he did so effectually as to lay the foundations of his present gigantic establishment and greatly benefit the world at large.

When water power is not available, steam engines must be employed, one of which for pressures up to 100 pounds per square inch, and having a cylinder 14″ diameter and 18″ stroke, is shown in the opposite plate.

In all cases the air is delivered into a cylindrical and dome-ended receiver, which, according to circumstances, varies from 2′ 0″ diameter and 8′ 0″ length, to 5′ 0″ diameter and 20′ 0″ in length. The number of drills these will



AIR COMPRESSING ENGINE.

drive ranges from 2 to 30, and the diameter of main air pipe from $2\frac{1}{2}''$ to 8″. Each receiver is made of steel plates, and fitted with safety valve, manhole, pressure gauge, blow-off cock, etc., as in steam boilers.

The whole scheme of tunnel excavating in rock may be thus briefly summarised. After the approaches on both sides have been sufficiently formed to allow the drilling machinery to open out a heading, the boring and blasting operations are continued with the object of enlarging it to the depth and width required. When these have been accomplished, the tunnel may be brick lined, or not lined at all, according to circumstances, and then finished off ready for laying the rails.

To enable all this to be done, however, a great many arrangements have to be made, which include the application of winding engines, locomotives, wagons, etc., for carrying away the rubbish. Sheds for the same, power houses, dynamite stores, cranes, stone-breaking machines, and mortar mills, spare-drilling machines and tools, and every necessary duplicate in case of breakdowns. In addition to these, if the work is extensive, a hospital, baths, dining rooms, dwelling houses, etc., have to be provided for the staff and workmen. As the work proceeds, telephones, electric lighting, and all other necessary appliances become more fully utilised, so that the undertaking may be facilitated to the utmost.

As reference has been made to the *Blasting Operations* which are found so useful in tunnelling and other similar work, it may be well here to note the Electric Shot Firing process of the Nobel Explosives Company, which is a distinct advance upon the old methods. This improved system is now most efficiently employed for a variety of purposes, including mining, tunnelling, railway construc-

tion, canal and dock work, submarine operations, etc., in all of which it has had the highest approval of Government authorities.

For general engineering the explosives of Messrs. Nobel, chiefly used in connection with Electric Shot Firing, are—Blasting Gelatine (the strongest known explosive), Gelatine Dynamite, Gelignite, and Dynamite Number 1, their application in practice being as follows:—

After the required hole or number of holes have been drilled in the rock, they are cleaned out for the reception of the blasting cartridges, which are connected to each other by means of copper wires externally united into one, and led to the exploder which may be placed in any suitable position.

Frictional electrical machines are very effective when in good working order, but as soon as they become damp their power decreases considerably. In consequence of the greater outlay for wires of high insulation, and the care and time expended in keeping the apparatus dry, these machines are not so suitable for blasting purposes as *Magneto Electric Exploders*, an external view of one of which is shown on the next page. This machine has been specially designed to meet the demand for an economical and reliable blasting appliance; its interior contains a number of powerful permanent magnets, having between their poles a Siemens' armature, to which motion is given by means of internal toothed gearing actuated by the handle shown in the view.

The working parts of each exploder are solidly constructed, and are enclosed in a strong dust-proof hand portable case of polished teak, which is fitted with terminals and firing key, etc., the machine being wound to fire Abel's tension and quantity fuses. When ready for

use the operator revolves the lever, and the explosion at once takes place without flame from the fuse or ignition of gas, and with complete safety and economy in time and labour.

MAGNETO ELECTRIC EXPLODER.

CHAPTER XXII.

RAILWAY BRIDGE BUILDING.

Bridge Building as a Science—Various kinds of Bridges—Considerations affecting Dimensions and Design—Leading Points in Construction—Primitive Rope Bridges—Steel Wire and other Suspension Bridges—Aerial Bridges for Inaccessible Regions—Enormous Spans — Examples from Practice — Advantages of the System — Table Mountain Waterwork Construction by its Aid—Comparative Economy of Rolled Joist and Plate Girder Systems — Rolled Joist Manufacture — Economical Extreme Lengths—Trough Girder System—Railway Warehouse Construction—Various Working Floor Loads—Table of Strengths of Steel Joists—Table of Strengths of Steel Columns—Machining Operations—Portable Hydraulic Riveting Plant—Wire Ropes.

AFTER what has been said in the last chapter, it will be easy for the reader to see that our good friends on the Baratanian Railway had, in the construction of their first, or "Bangshot tunnel," only run upon the lines previously indicated. As the material to be worked upon was good solid granite, which the rock drilling machines treated very lightly, and as no quicksands or cataclysms of water were encountered, everything had progressed to the entire satisfaction of the contractors, Messrs. Brown and Jones, and also of the resident engineer. The exact length of the tunnel was one mile, but no sooner was the hill well cleared through which it passed, than the above gentlemen were confronted by the Derwent, which had to be crossed. Here, therefore, we must make a few observations upon *Bridges*, as these form the usual means of crossing, not only rivers and estuaries, but valleys, ravines, and all more or less sudden depressions.

Bridge building, as a practical science, is one of the most valuable of the age, and the importance of this form of structure may be gathered from the fact that it forms a connecting link between villages, towns, provinces, and countries which would otherwise remain isolated. Examples of this are to be found, amongst many others, in the Menai Straits' Britannia bridge, through which an enormous amount of the Irish passenger and goods traffic is admirably maintained, and in the Niagara bridge, which acts in the same way for the United States and Canada.

The origin of the Bridge is lost in the mists of antiquity, but probably the stepping-stones still in use for crossing shallow streams gave the primary idea, the deeper spots being waded across; hence, we have the names of towns thus originated, such as Dept*ford*, or "deep ford;" Ox*ford*, Dart*ford*, and so on. Perhaps, however, the real commencement of bridge building was a plank thrown across a ditch, or a tree spanning a stream too wide to jump across. Indeed, to this day, the tree bridge forms at once an excellent and most convenient method of transport when nothing better is available.

Between the above and the colossal structure on the Forth, there is an almost endless variety to be found. On the one hand we may have a plank costing a few pence, and on the other, prodigious works upon which millions of pounds have been expended, for the purpose of uniting nations, and even empires, the railway bridges being the head and front of them all. These, as a class, are divided into the beam or girder, the arched, the suspension, the floating, and also compound forms too numerous to mention. The materials employed are steel, iron, timber, stone, brick, etc., in every case, however, resolving themselves into two distinct portions—the substructure, and the

superstructure; the former consisting of abutments and piers, and the latter of everything that singly, or in combination, sustains the roadway.

The dimensions and design of a bridge depend upon the peculiarities of the obstacle to be crossed, and upon the nature of the expected traffic. As these are continually changing, according to circumstances, it will be seen that there is unlimited scope for the exercise of high-class talent in the design of the cheapest and most suitable structure, the peculiarities of site, and facilities for manufacture and erection being two of the leading considerations. In out-of-the-way parts of the world, however, where timber is plentiful and within easy reach, convenience in construction is more important than economy of material. For railway and ordinary road purposes, the engineer has primarily to consider whether a small number of large spans, or a large number of small ones, will be most economical, the former being most suitable where foundations cannot well be obtained, or where the structure is lofty. As an example of this on a colossal scale, it may be noted that the extremely deep channels on each side of Inchgarvie Island on the Forth compelled the engineers to employ two main spans, of 1,700 feet each, in preference to shorter ones, as intermediate piers were impracticable.

Amongst other considerations are those affecting prices of materials, labour, and transport, which, singly, or in combination, greatly influence the design of a bridge. The traffic to be accommodated will determine its width, and also the load the superstructure has to carry, which, in the two latter cases, may vary from those suitable for the smallest footbridge to the widest railway bridge for several lines abreast. *Beauty* in outline and detail is addi-

tionally essential; this, however, requires not only good taste in design, but practical experience of a high order.

Before entering upon the finished structures of to-day, it may be well to note a few of those which formed the germs of the modern systems, and which for usefulness and economy were perhaps not inferior, in their own way, to any of the present time, nor, indeed, will they ever be, in places where primitive simplicity alone is necessary.

For these we have to look to many spots in India, China, South America, and other distant lands, where the requirements of the traffic are extremely simple, and where the materials of construction are easily obtainable. Although the suspension system is supposed by some to be of only recent date, we must, nevertheless, go a long way back to discover its origin. Take, for example, the early rope bridges of Thibet and Peru, which have sometimes had to cross rivers or chasms of immense depth in a rough and ready style. In these cases, two parallel ropes of twisted hide, or fibres of plants, were stretched across the gorge, and fastened at the ends to trees on the banks. Over these ropes a rough but very light timber roadway was laid, thus forming a complete structure, which, in span has been known to reach as much as 600 feet. To this day the same system is popular in isolated mountain districts, but with ropes of steel wire instead of hide, etc.

Good recent examples of extremely simple, elegant, and inexpensive *Steel Wire Suspension Bridges*, for the transit of foot passengers, horses, cattle, etc., are to be found in the practice of Messrs. Harper. Although these structures have a very slim appearance, they are nevertheless perfectly safe, owing to the enormous strength of their material, and on account of the small amount of surface exposed to the wind, everything, also, is protected from

rust by being galvanised. A very useful feature of this style of bridge is the ease with which it can be transported and erected, which is of immense importance in foreign parts, where skilled labour may not be available. The spans of these generally range from 50 feet to 300 feet.

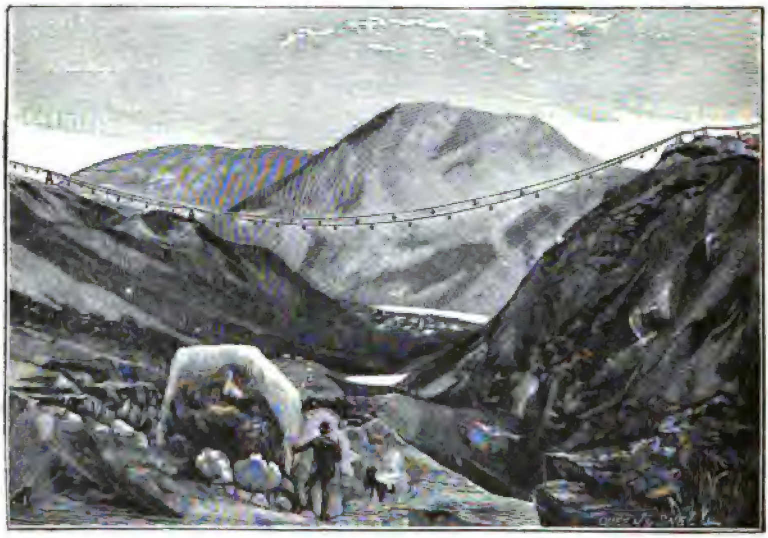
In these cases the piers are of iron columns, but in larger bridges stone or brick is used instead, the cables being led from the top of the piers to a secure and convenient anchorage. This type of bridge is most useful for *long* spans, because it can be made much lighter and more cheaply than those of the girder description, and, at the same time, stiff enough to carry proportionately heavier loads than small bridges, where the passenger traffic may much more easily produce deformation of the structure.

The suspension systems have been most usefully adapted in recent years to the *Aerial Bridges or Ropeways*, now so popular in mountainous districts for the transport of minerals, where no other method is available. These consist of wire ropes, and are divided into two classes—the running, and the fixed. The former consists of an endless power driven rope, from which loads of one to five hundredweight are hung by peculiarly shaped pendants, which enable them to be transported at the same speed as the cable. By means of special arrangements, these loads are enabled to pass the supporting pulleys at convenient points, and also to leave the rope at the termini.

The fixed system consists of two stationary ropes, supported, if necessary, at various points, the weights being carried by suspenders hanging from the ropes, and provided with wheels that safely fit them. A small line keeps them in motion, the arrangements for passing the points of support and arriving at the terminals being very similar to those for the first named system. The application of

both of these may be gathered, in a general outline manner, from the annexed engraving, which is of one of many similar undertakings by the Ropeways' Syndicate of London.

Here we have a ravine spanned by two cables, the greatest distance between the supports being 1,220 feet. By using a number of load carriers of small size, as shown, they become much more easy to handle, and, at the same



MOUNTAIN ROPEWAY CROSSING A VALLEY.

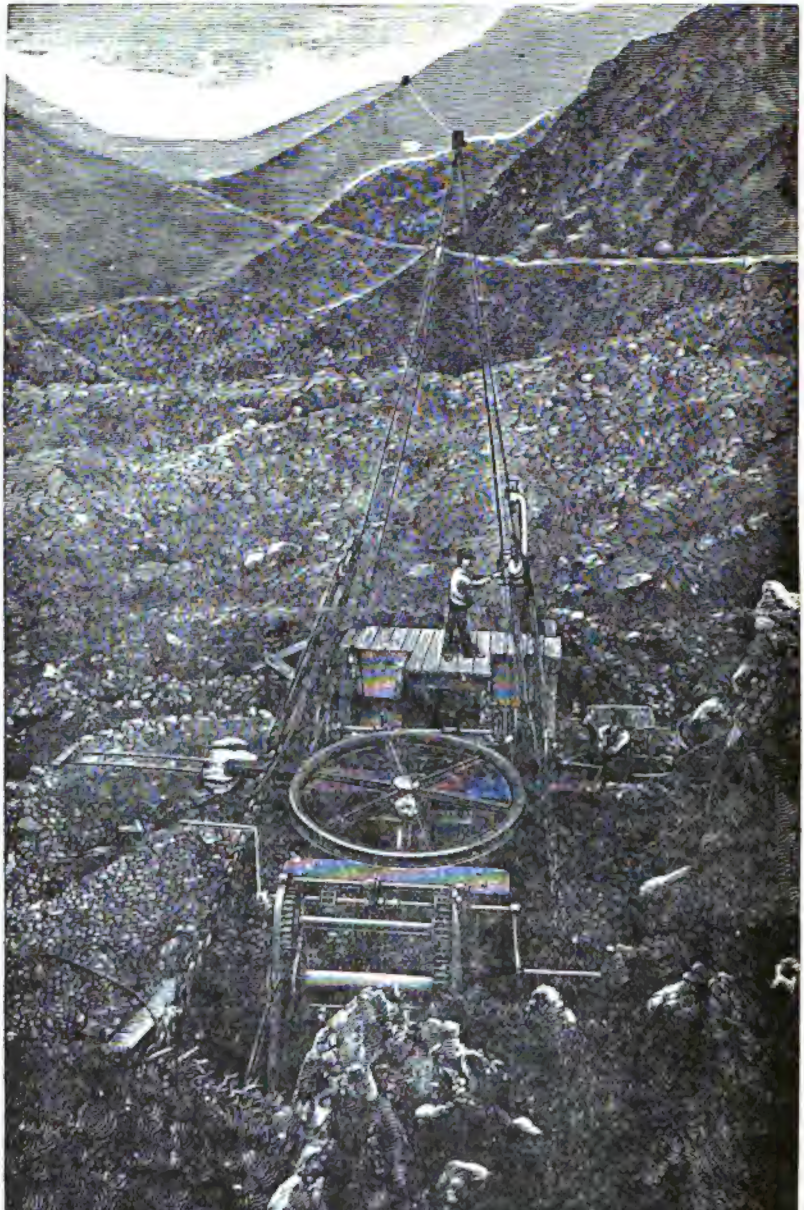
time, lessen the strains on the ropes, owing to their more evenly distributed nature. When the buckets reach the point of delivery, their contents are discharged through the bottom by means of a hinged door, which is worked by a lever attached to their sides.

Each of the above methods of transport has its own special advantages. Of the *fixed* system it may be said

that perhaps no cheaper or more efficient arrangement can be desired for carrying loads below one ton across rivers, etc., up to 2,000 yards between the sides. With this plan little more than two fixed ropes are required, having two light hauling lines and suitable carriers. Where sufficient fall occurs, and the produce has to be delivered on lower ground, the descending load can be made to haul up the ascending empty buckets. Where, however, the materials have to *ascend*, or the terminals of the fixed rope are nearly equal in elevation, the motive power employed need be very small, owing to the insignificant amount of friction caused by the rolling load.

To make the fixed system as intelligible as possible, we give in the plate on next page a view of an *Aerial Ropeway in the Pyrenees*, by Messrs. Bullivant and Co., where minerals are carried from a point 995 feet above the lower platform in only two spans, one of which is 600, and the other of 1,000 yards, 200 tons of material being delivered per day, at an average cost of 2d. per ton per mile. The large pulley for actuating the hauling line is clearly shown, as well as the rope tightening and slackening gear, which, on the one hand, prevents too much dip in the rope, and on the other allows it to be laid on the mountain side for inspection and repair.

The subsequent illustrations represent a portion of the wire ropeway erected by the same firm at Gibraltar, to the designs of Mr. W. Carrington, for H.M. War Office. In the mountain view we have a side elevation of the line coming down the steep side of the rock, and in one large span reaching unobstructedly to the landing place. The other engraving shows one of the piers in detail, and also the main ropes and box traveller attachments, with hauling line, as the above is on the fixed system previously men-



AERIAL ROPEWAY IN THE PYRENEES.

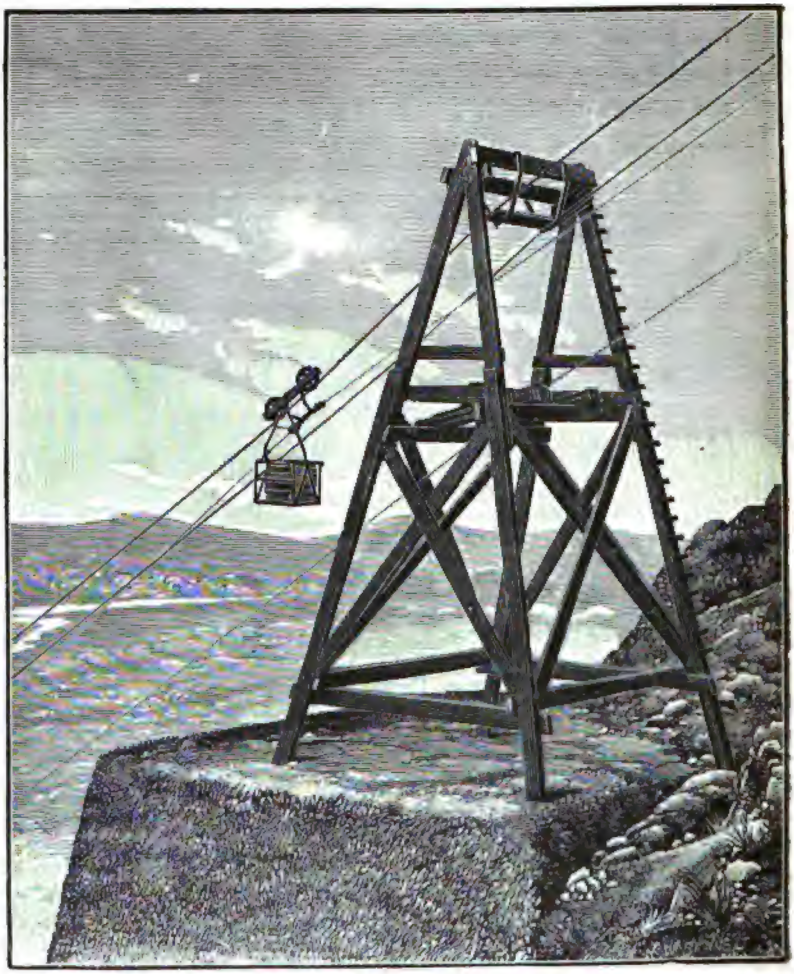
tioned. In this case, soldiers and stores only for the upper regions of the fortress are transported.

Through the use of the above systems, traffic up to 500 tons per day can be carried economically over portions of a country *utterly inaccessible* by any other means, thus forming not only an admirable source of supply to ships and railways, but also to the establishments where the crude

AERIAL ROPEWAY AT GIBRALTAR.

materials are manufactured into the finished productions. One of the most extraordinary of recent applications of the system is to be found at Cape Town, the water supply of which is taken from a point on Table Mountain, 2,168 feet above sea level, and so completely isolated and inaccessible by ordinary methods, that the works could only be carried out in this most difficult locality by means of one of

Mr. Carrington's special ropeways, which enabled the materials, etc., to fully 15 cwt. each, and workmen, to be



ONE OF THE SUPPORTING PIERS OF GIBRALTAR ROPEWAY.

transported to the scene of operations; the ropeway now being used for maintenance and other purposes.

Some of the advantages of wire ropeways may be thus briefly stated:—

(1.) They avoid the expense of cuttings and embankments.

(2.) No bridges are required over rivers and ravines.

(3.) Lines can be constructed and worked on hilly ground almost as cheaply as on plains, and on inclines impracticable to ordinary railroads.

(4.) They are not affected by floods or snow.

(5.) They can be readily moved from place to place.

(6.) They can be used for the transmission of power at the same time as goods. In short, there is everything in the system to render it one of the most easily applicable and useful of the present day.

The success of the aerial system to which we have referred lies primarily in the fact that steel wire ropes made by improved machinery have not only immense strength for their diameter, but, owing to this being relatively so small, their weight is much reduced, and their flexibility increased. Some idea of the means employed to obtain these qualities may be gathered from the fact that a bar of 27 ton steel may have its tensile strength raised to 50 tons per square inch by rolling to $\frac{1}{4}''$ diameter, and cold drawing to $\frac{1}{8}''$ diameter. The strength is still further increased by the processes of annealing and hardening, and also tempering in a peculiar furnace and bath, whereby the tensile strength of the wire may be again increased about 100 per cent.

Wire, as now manufactured, from $\frac{1}{4}''$ to $\frac{1}{1000}$ of an inch diameter, is much more extensively employed for mining, haulage, and various other purposes than is generally known. For ordinary work, however, it does not vary in size to any great extent, although it differs largely in

quality. We therefore find, from the practice of Messrs. Bullivant, that while the average strength of bright hard-drawn iron wire is about 35 tons per square inch of section, that of Bessemer steel is, say, 40 tons; mild Siemens-Martin steel about 60 tons; high carbon steel about 80 tons; crucible cast steel, 100 to 110 tons; and so on up to about 175 tons per square inch, according to the process of manufacture. These wires, when made into ropes by the most improved methods, produce results in wear as well as in strength which are often astonishing, especially when used for the aerial purposes we have tried to describe.

People try to obtain special excitement nowadays by means of switchbacks, marine railways, and other things, which perhaps the reader knows more about than the writer. If so, may the latter kindly suggest for the sake of novelty a trip along an apparently gossamer thread aerial ropeway, whose greatest span on a steep slope across a valley of profound depth is 1,500 or 2,000 yards, the speed being at the rate of 40 to 50 miles an hour. The mental exhilaration of an eagle swoop or bird flight passage like this, once experienced, especially when the surrounding circumstances were of the most awe inspiring nature, could never be forgotten, and no doubt Mr. Carrington would be willing to give permission to those who desired such a journey over any of his grand undertakings.

In machinery of various kinds the details are so diversified and complicated that it is impossible to make them without the aid of many drawings, whose excellence is due to the skill and experience of the designer. Such, however, is the practical foresight of the Rolling Mill people that they supply us with ready-made materials in the form of plates, bars, angle irons, tee irons, channel irons, rolled

joists, etc., all of which are employed in immense quantities in railway and other bridge and girder work.

Plate Girders, as now made, show very clearly how the above sections of steel predominate in such structures. It may be noted, however, that although the bars are rolled to the exact size, ready for application, it requires considerable skill on the part of the designer to select those which combine the greatest strength with economy, even in elementary girder work, one section being, perhaps, quite as strong as another, but neither so suitable practically, nor so economical commercially.

The simplest of all beams is the rolled **I** joist, which is made in various sizes, from 3″ by 1½″ to 20″ by 7½″. This joist is used very extensively for carrying the floors and walls of buildings, and in many other ways where economy in construction is most desired. In bridges, however, the plate girder and other systems, in their various modified forms, are generally preferred, on account of the lightness which a more scientific distribution of material will permit, and also owing to greater convenience in manufacture.

Formerly, rolled joists were made of iron which was not remarkable for strength, and occasionally produced cracked webs; now, however, they are made of steel of faultless quality. The system of manufacture at the works of Messrs. Dorman, Long & Co. is to cast ingots of three tons each by the Siemens-Martin open hearth acid process. These are re-heated in special furnaces, and then passed on to a 36″ cogging mill, driven by a pair of powerful reversing engines. The bloom thus produced is sheared to the required lengths, all of which are re-heated, rolled, sawn while hot to the specified dimensions, then straightened, and finally sent to their destination.

As the extreme ordinary price lengths of plates, flat

bars, joists, angle irons, etc., greatly influence the detail design of bridge and girder work, it is useful to know what these are in each case, so that the extra rates may be avoided. To attain this end, the above firm now roll flat bars up to 18″ × 1″ 40 feet in length—bars 4″ square and 8″ diameter 24 feet—angles 6″ × 6″ × $\frac{7}{8}$″ 50 feet, and tees 5″ × 3″ × $\frac{5}{8}$″, and channels and joists 12″ deep up to 36 feet in length, extra prices being charged for these and for larger sections if of greater lengths.

Leaving out of sight the very numerous combinations of those sections, we come to the highly popular trough system of construction which was originally intended to take the place of cross girders in bridges, and to provide a water-tight flooring at the same time. So fully, however, has this system become developed, that in the overhead road bridges of railways, etc., from 12 to 36 feet span, these sections can now be made so strong that even the outside girders may be dispensed with. In this case the troughs run longitudinally, their ends resting upon stone abutment bearings, the sides being formed to receive the stanchions that carry gas pipe hand rails. When this is done, and the roadway filled in, the bridge is finished.

A still later excellent bridge floor on the same system is that of Mr. Gerald Barker, of London, in which great strength and convenient attachment of cross sleepers are fully attained. Its construction is very simple, and the whole of the operations of erecting and machine riveting can be easily carried on without any scaffolding whatever.

As in railway warehouses, stations, etc., enormous quantities of rolled joists are used when plate beams would not be suitable. Messrs. Dorman, Long & Co. have experimentally ascertained the strengths of the various

sections manufactured by themselves, some of which we have been kindly allowed here to note.

Beginning with the smallest section and ending with the largest, specially prepared tables have been given for each up to 32′ 0″ span, but it is not advisable to employ beams having a less depth than one-twentieth of the span, otherwise deflection may result. In these joists, the working tensional strains are taken at 10·6 tons per square inch for permanent dead loads not liable to variation; 8 tons for ordinary live weights applied gradually; and 6·4 tons for the same when rapidly applied and for machinery in motion, these being respectively $\frac{1}{3}$, $\frac{1}{4}$, and $\frac{1}{5}$ of the breaking strain, due allowance being made for rivet holes.

The irregularly disposed and complicated loads which have to be specially considered when designing girder work need not be referred to, as those of the equally distributed class are generally used for walls and floors. The former produce greater or lesser strains according to their dimensions and the share of floor, roof, and other weights they may have to sustain. The latter, however, are very simple, as the weight of the materials composing the floor—or dead load—and the weight of the persons or goods which constitute the live load are alone considered.

The dead weight of a fire-proof floor of small steel joists and 6″ of coke breeze concrete may be taken at 70 pounds per square foot, and the live load for dwellings or offices similarly at 84 pounds additional, or 154 pounds in all; but in buildings where crowds assemble, or where heavy goods are stored, the total loads to be provided for will be somewhat as follows:—

Public Halls or Schools	180 pounds.
Warehouses	200 to 400 ,,
Heavy Machinery	300 to 500 ,,

For obvious reasons machinery floors require special treatment, but the weight of grain, cotton, sugar, etc., loads per square foot, should be experimentally ascertained at the maximum possible depth of piling to ensure safety. When the equally distributed and concentrated loads on a girder have been worked out, the strains at the various points have to be discovered so that the proper section of joist, either simple or compound, can be selected. This may be done either in a learned style, or by the use of graphic diagrams, the latter being the best, since by means of parabolas or triangles for simple loads, or both in combination for those of complex nature, the strains at any point may be measured by scale, and the chances of error almost entirely eliminated.

The tables of the strength of beams of all sizes by the firm we have named are fully worked out in every respect; here, however, a few simplified examples of the joists most in use will be sufficient, the loads in all cases being equally distributed, the letters A, B, and C indicating those which produce the various tensional strains previously mentioned. These, and other beams, may be placed in sets of 2, 3, or more side by side, and plated when carrying a thick wall, or superposed in riveted pairs when depth and great strength are needed.

As all the working loads given in the Table are equally distributed, the beams will only carry half the weight if centrally applied, one-fourth when equally distributed on a cantilever of same span, or projection from support, and one-eighth if placed at the end. The maximum *shear* at each of the bearings is, in the first two instances, equal to $W \div 2$, and to the full weight for each of the cantilevers.

Not only are rolled joists and other sections used for

TABLE OF SAFE DISTRIBUTED WORKING LOADS, IN TONS, ON STEEL ROLLED JOISTS FOR DIFFERENT SPANS AND VARIED STRAINS.

Sectional Dimensions in inches.	Weight in lbs. ♯ foot.	12 feet Span.			14 feet Span.			16 feet Span.			18 feet Span.			20 feet Span.			22 feet Span.			24 feet Span.		
		A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.
20 × 7½	89	—	—	—	83	62	50	73	54	43	65	48	39	58	43	35	53	39	31	48	36	29
18 × 7	75	—	—	—	64	48	39	56	42	34	50	37	30	45	34	27	41	30	24	37	28	22
16 × 6	62	53	40	32	45	34	27	40	30	24	35	26	21	32	24	19	29	21	17	26	20	16
15 × 6	59	48	36	29	41	31	25	36	27	22	32	24	19	29	21	17	26	19	16	24	18	14
14 × 6	57	44	33	26	37	28	22	33	24	19	29	22	17	26	19	15	24	18	14	—	—	—
13 × 5	41·5	27	20	16	23	17	14	20	15	12	18	13	10	16	12	9	14	11	9	—	—	—
12 × 6	54	36	27	22	31	23	18	27	20	16	24	18	14	21	16	13	—	—	—	—	—	—
12 × 5	39	25	18	15	21	16	12	18	14	11	16	12	10	15	11	9	—	—	—	—	—	—
10 × 6	45	25	19	15	22	16	13	19	14	11	—	—	—	—	—	—	—	—	—	—	—	—
10 × 5	35	19	14	11	16	12	9	14	10	8	—	—	—	—	—	—	—	—	—	—	—	—

beam and various purposes, but they are also extensively employed in place of cast iron in the columns and stanchions of railway warehouses, etc. These columns may consist either of plain joists, or combined joists and plates, or channel irons and plates, or flanged segments of a circle, but in any case they make a very strong, light and efficient support for heavily loaded floors.

The following Table, by Messrs. Dorman, Long & Co., gives the calculated breaking loads in tons of their own single joists used as columns with the ends fixed; the working loads, however, should not exceed *one-fourth* for stationary, and *one-sixth* for moving loads, the tensile breaking strength of the material for beams and columns alike being 28 to 32 tons per square inch, elongation 20 per cent. in a length of 8″, in accordance with the Admiralty and Lloyd's rules. The importance of having columns such as the above may be gathered from the fact that warehouse and other buildings in this country, and in America, have now attained colossal proportions, and the weights to be carried have become enormous, one recent building in New York, for example, being fully 350 feet in total height, a great part of which is carried by 29 steel built columns, each of which carries varying loads up to 2,000 tons. Amongst other important examples of their use may be mentioned the Liverpool Overhead Railway, where thousands of them have been employed as supports to the line, each column being box formed by means of two channel irons to which two outside plates are riveted.

The first thing that strikes one on entering the works of the Cleveland Bridge Company is the systematic manner in which the materials are dealt with as they arrive in the yard. Plates are unloaded at the flattening machines to be freed from all irregularities at the outset. They are then

passed on to plate edge planing machines, after which they are taken to the marking shop, and subsequently to the

CALCULATED BREAKING LOADS, IN TONS, ON STEEL SINGLE JOIST COLUMNS.

Section.	Weight per Foot in lbs.	Length of Column in Feet.											
		7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	18.	20.
in. in.													
20×7½	89	628	607	582	563	542	514	488	456	435	404	353	309
18×7	75	523	508	484	467	445	423	401	375	352	329	282	245
16×6	62	407	394	369	346	326	301	277	255	230	211	182	155
15×6	59	395	377	358	333	316	292	266	246	226	208	177	152
14×6	57	374	356	341	321	300	283	258	237	225	204	174	150
14×6	46	308	293	278	259	241	224	206	189	171	153	135	115
12×6	54	367	350	337	321	302	283	262	242	222	206	171	153
12×6	44	298	286	274	260	245	230	214	196	182	169	143	124
12×5	32	200	188	174	160	144	131	111	107	99	89	74	63
12×5	39	232	226	209	189	171	155	139	127	115	105	88	73
10×6	45	304	292	279	267	251	236	218	201	185	172	147	127
10×5	35	218	203	190	172	156	143	127	115	105	95	81	68
10×5	29	184	173	162	149	136	124	113	100	90	85	70	60
9×7	58	409	397	383	370	356	338	320	304	283	266	232	201
8×6	35	239	228	218	208	196	183	170	156	145	135	114	99
8×4	19	104	93	82	72	65	58	50	45	40	35	29	23
7×3¾	16	83	73	63	55	49	44	39	35	31	27	22	18
6×5	25	160	151	142	133	124	112	102	93	85	78	66	58

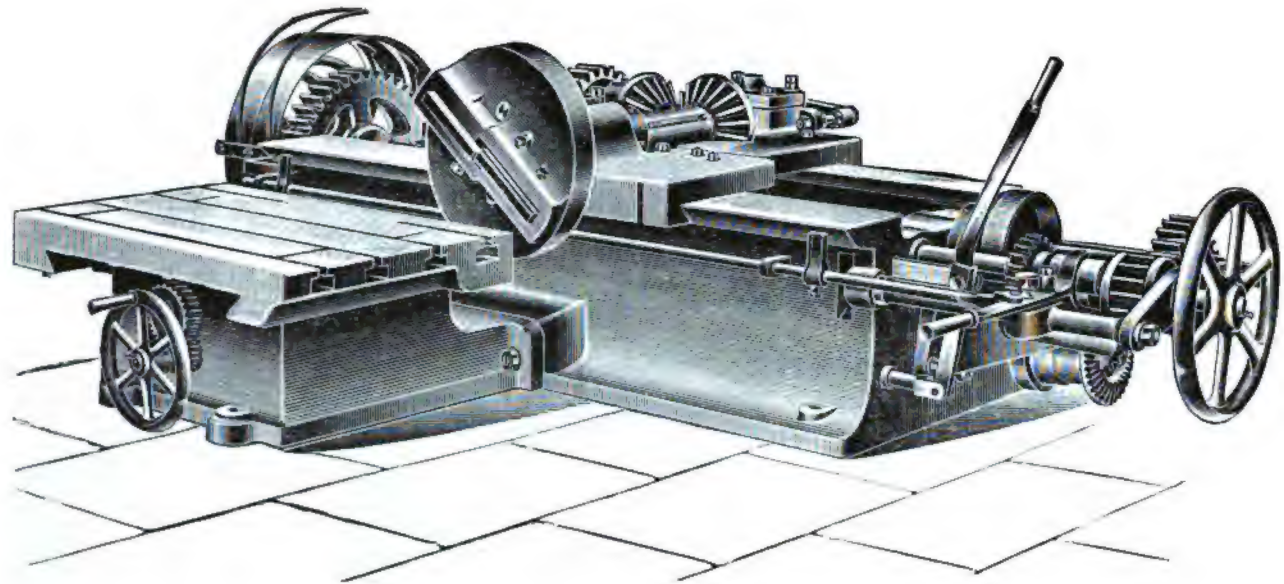
punching and drilling machines, where they are conveniently operated upon. Angle and tee bars are similarly treated, thus bringing forward, in completed form, the

various details out of which even the largest bridges are to be constructed.

In modern work of this nature the punching of plates has become almost obselete, as the once barbarous method of trueing up the irregularly perforated rivet holes caused so much imperfect riveting when three or more plates were superposed in flanges. To allow this desirable end to be accomplished, the *Multiple Drilling Machine* was introduced, and so successful has it proved that not only are many holes bored at once through several thicknesses of plates, but there is an exactness of pitch and truth of aperture unattainable in any other way, which is of great advantage to the bridge when in actual service.

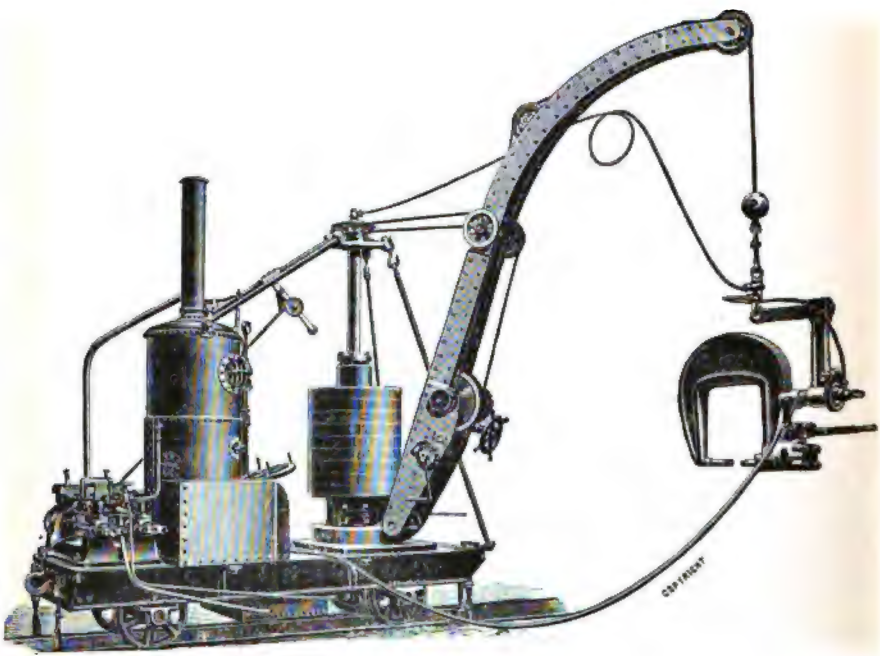
As *Cold Steel Sawing Machines* have been found invaluable in bridge building establishments, we give on next page an example of one of these of the most improved class, by Messrs. Isaac Hill & Son, which can also be used for facing or ending-up purposes. As will be seen in the view, all the movements of the machine are under the most perfect control, and, when required, the cutter head can be removed from the spindle, and a saw employed instead. There are several special varieties of these machines, but for heavy work the above is very suitable.

It may be added that while the hot steel saw is only suitable for fairly approximate cutting to length on account of irregular contraction of the metal operated upon, the cold steel saw, on the other hand, is sufficiently accurate for bridge and girder work. Where, however, end finishing of beams, columns, etc., to exact lengths is required, the cutter disc is very handy, as it rapidly performs all that is needed, a separate table being bolted to the top of that shown in the view to raise the level sufficiently for saw cutting.



FLUSH-SIDE COLD STEEL SAWING AND ENDING-UP MACHINE.

By means of another very useful and portable machine having a flush side horizontal saw, the iron or steel built-up pile columns for bridge piers, etc., can be truly cut to a dead level throughout with very little trouble when fixed in position at site, the motive power being either manual or otherwise, according to circumstances.



PORTABLE HYDRAULIC RIVETING PLANT.

We cannot perhaps do better than close this chapter by referring to the above complete *Portable Hydraulic Riveting Plant*, by Messrs. H. Berry & Co., of Leeds, for riveting up bridges during erection. In this case we have conveniently arranged the pumping engines, boiler, riveter, accumulator, and crane. The pumps are of the duplex

direct acting type, and the accumulator has a differential ram which acts as a guy for the crane. The latter is worked by hand, and can be slewed round so as to suspend the riveter over either bridge girder, and although the water pressure is 1,500 lbs. per square inch, and gauge of rails 4′ 8½″, both may be altered to suit.

The maximum pressure on the rivet is obtained by the employment of a special intensifier, which forms part of the apparatus, and can be automatically thrown into action, the whole operation of riveting being performed by means of one valve lever.

The valve arrangement is simple in construction, positive in action, with few wearing parts, and of very compact design, the variable power thus produced effecting a saving of about 50 per cent. of the water required in working.

CHAPTER XXIII.

THE ELECTRICAL ENGINEERING OF RAILWAYS.

The Early Experimentalists—Electrical Engineering of To-day—Paradoxes of Electricity—Works of Messrs. Scott & Mountain—Electrical Terms Described—How a Dynamo becomes a Power Motor—Working Specification of a Dynamo—Its Details—Foundations—Setting in Position—Examination before Starting—The Trial Start—Supervision and Maintenance—Dynamos for Electric Lighting—For Power Transmission—Method of finding Power of a Motor—Useful Calculations—Losses in Efficiency—Size of Generator for Driving Motor—Tables of Particulars of various Dynamos.

THE Science and practical development of *Electrical Engineering*, as we now have it, has been due to the sustained efforts of many minds during the nineteenth century, the talented philosophers of which paved the way for its useful application during recent years.

Amongst those of the first-named period may be mentioned *Volta*, who was so noted an Italian experimentalist that the terms "Volt" and "Voltaic" are derived from his name. To *Ampère*, a French philosopher, we owe another well-known term. In 1827, *Dr. G. S. Ohm* published a valuable book on this subject, and from this gentleman we have an additional term. These three scientists, therefore, whose names have thus been immortalised, may be said to have mainly helped to introduce a system which has been so immensely improved and developed as to indicate future extensions in practice so enormous as to be almost beyond conception.

The electrical engineer of to-day, although supposed

to belong to a new race of beings, is neither more nor less than the mechanical practitioner promoted a step higher, and while still utilising in the fullest degree his former experience, is adapting it to a previously neglected but mighty force of nature.

The power referred to has been described by Mr. W. H. Preece as a "subtle and invisible force that pervades the earth, and permeates the heavens, whose energy can be utilised when desired, but which disappears when done with—like the snowfall on the river, a moment white then gone for ever.

The *paradoxes* of electricity are more numerous than some would imagine. For instance, though invisible it can be made to produce the most powerful light known, and although noiseless it can create deafening peals of thunder, or operate the most delicate of all acoustic instruments—the telephone. Although existing in unlimited quantities of powerless form in and around the earth, it can be used to drive motors as powerful as a great steam engine, or as minute as a watch. Although we cannot touch or handle it, yet we can measure it with the greatest accuracy; and although it has apparently no velocity, its speed is almost infinite. Although not a chemical, it produces very powerful chemical action; and although it cannot be burnt, it nevertheless produces the greatest known heat. Amongst other paradoxes, perhaps the greatest is that, although the laws of electricity are more definitely determined than those in many other branches of science, we cannot say what this wonderful agent really is, and so for want of a better term we call it a "fluid."

Like water power, it can be stored up or accumulated for future use, and it possesses the great advantage of being extremely portable, and capable of having its direc-

tion and intensity easily changed. It can be taken round corners into all sorts of nooks, crannies, and crevices, and up or down hill, much more easily than gas or water, and from one central station it can be made to sweep very many miles around. Another of its peculiarities is the ease with which the waste forces of nature can be utilised for electric storage purposes, so that energy may be distributed for a great variety of purposes, even on the most colossal scale.

To make the subject as intelligible as possible, we may here describe the Electrical Engineering Works of Messrs. Scott & Mountain, at Newcastle; some of their methods of producing electricity; and, from a variety of sources, in this and the next chapter, its application as a lighting agent and as a motive power; and lastly, the various systems employed for driving dynamos to the best advantage.

From 1882 to 1890 the above establishment was carried on under the proprietorship of Messrs. Ernest Scott & Co. for the manufacture of marine and general work, but upon the accession of Mr. Mountain to the firm, in 1889, the electrical department was added, and in this alone the productions have become very comprehensive, as they include the fitting up of plant and machinery for electric lighting on land and sea, transmission of power, electro-deposition of metals and alloys, and pumping, winding, hauling, welding, etc., as complete installations.

The *Machine Shop* is a spacious building, chiefly filled with constructive machines, such as those we have described in former chapters. A leading feature of their driving gear, however, is the application of independent electric motors, which have been found convenient and economical, as the current is taken from the light installa-

tion of the works. The electrical portion of the establishment comprises two large shops, in which various operations are performed, including the winding of armatures and magnet coils, and other work of a similar nature, ready for assembling; dynamos, motors, and other machinery of this class being adjacently fitted up and tested.

The ordinary terms used by electricians may be explained in the simplest manner as follows:—

Electro-Motive Force, *Potential*, or *Volts*, are one and the same thing, and these terms apply to the pressure of the current in the same manner that pounds pressure per square inch is used by engineers. The former pressure is usually written E. M. F.

Ampères, or *Current*, is the quantity of electricity given by a dynamo or passing along a wire, and may be compared with the quantity of water or steam passing through a pipe.

Ohm, or *Resistance*, is the term applied to the unit of resistance. The standard Ohm is approximately equal to the resistance of 129 yards of copper wire $\frac{1}{16}$ inch diameter, and may be compared to the friction opposed to water or steam whilst passing through a pipe.

Watts, or *Volt-Ampères*, may be thus described:—A dynamo, when working, gives a current of so many Ampères at a pressure of so many Volts. For instance, suppose the machine gave 100 Ampères at 105 Volts pressure, then:—

$$100 \times 105 = 10{,}500 \text{ Watts.}$$

A *Horse Power* in mechanical engineering equals 33,000 foot lbs, and is represented in electrical engineering by 746 Watts, therefore, taking the output of the above dynamo, and dividing it by 746, we find that with a safe practical allowance of 80 per cent. efficiency, owing to

friction, etc., the required Brake Horse Power at the dynamo pulley for driving purposes will be as follows:—

$$\frac{10{,}500 \times 100}{746 \times 80} = 17{\cdot}59 \text{ B. H. P.}$$

The *Indicated* horse power of the driving engine necessary to produce a given Brake H. P. varies according to circumstances, but may be taken as 25 per cent. extra on the average. Therefore to produce the above B. H. P. on the pulley we must have 17·59 + 25 per cent. = 21·98—say 22 I. H. P. in the engine.

According to Professor Silvanus P. Thompson, a Dynamo "may be described as a machine for converting mechanical power into energy in the form of electrical currents, or *vice versa*, by the operation of rotating conductors—usually in the form of coils of copper wire—in a magnetic field. This definition is applicable to all machines whose action is dependent upon the principle of magneto-electric-induction, discovered by Faraday in 1831."

Otherwise expressed, a Dynamo is a machine so actuated by a steam or other engine as to *generate* electricity, whereas, if the same dynamo received a supply of electricity through a cable or wire, from a more or less distant source, for driving purposes, it then becomes a *motor*, the machines being thus exactly alike, but worked under different conditions.

A Dynamo consists of three principal parts—the armature, the field magnets, and the commutator—the *General Specification* for the guidance of designers of dynamos being quite as minute as that of their driving engines. From one of the documents upon which the "Tyne" dynamos of Messrs. Scott & Mountain are built, we gather the following leading features of construction.

"The *Armature* will be of the cylinder type, the core

being made of the softest Swedish charcoal iron discs, securely cramped together by means of a gun metal driver, the whole being securely fixed to the spindle by a key and lock nuts.

"The *Armature Conductor* will be wound in separate sections upon the core at right angles to the direction of rotation, and thoroughly insulated from it, and further protected from injury by special varnish.

"The *Armature Protection Covers* consist of a polished metal guard fixed on each side of the field magnets, and also a perforated guard above and below the armature, all of which are so fitted as to render damage to the latter an impossibility.

"The *Field Magnets* will be of the softest wrought iron, united by two pole shoes embracing the armature, the magnet being recessed into the poles and properly secured in position. The *Magnet Coil* will be wound on a separate wrought iron case which enables it to be readily replaced or renewed, the coils and connections being carefully insulated from the frame of the machine and varnished, or additionally protected by sheet steel lagging, if desired.

"The *Commutator* will be of pure copper hard drawn to the required section, the copper segments and mica strips being mounted upon a phosphor bronze sleeve, and so held in position by a coned collar at one end, and a coned washer at the other end secured by a circular nut, as to enable the commutator to be readily removed and the copper segments quickly replaced.

"The *Spindle* will be of the best mild steel, highly finished, and provided in the centre with a collar and lock nuts for securing the armature in position. One end will be so formed as to allow the pulley to be firmly keyed in the usual way, the other end being screwed and fitted with

a steel feather and circular lock nut for the attachment of the commutator.

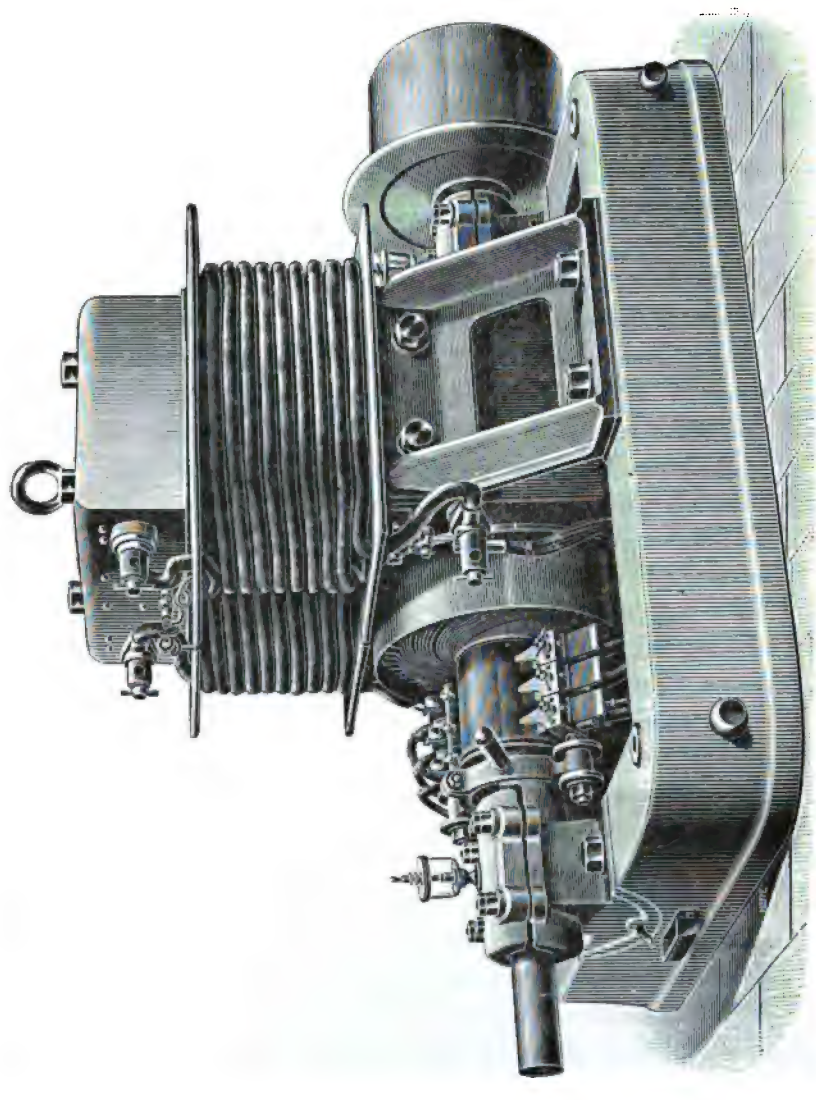
"The *Bearings* will consist of cast iron pedestals, fitted with round gun metal brasses lined with white metal, and capable of exact adjustment for wear.

"The *Brush Holders* will be mounted on two wrought iron spindles, each of the former having a throw off catch for holding the brush off the commutator, an adjusting screw and spring for regulating the tension of the brush on the commutator will also be provided. Pointers will be fitted to the machine so that the correct position of the brushes can be ascertained, and these will stand at an angle of about 50° to the surface of the commutator.

"The *Bed Plate* will be of box section, planed on the under side and at all other bearing surfaces, stiffening ribs being cast inside to give rigidity." Its general design, as as well that of the foregoing details, will be seen in the view we have given of a "Tyne" Dynamo, in which it will be noted that the centre of the spindle is kept very low to avoid vibration when running. By boring the Magnets and the seats of the end bearings of the bed plate at the same time the removal of one of the latter enables the armature to be readily withdrawn.

"The *Copper Conductors* used throughout the machine will be of 100 per cent. conductivity. The armature conductors will be insulated, and the magnet wire doubly covered with cotton, all outside layers of wire being well insulated and varnished.

"*Before leaving the works* the machine will be carefully tested, and guaranteed capable of giving the stated output on a continuous run of 12 hours, without sparking on the commutator, or undue heating of the armature or magnet coils."



"TYNE" DYNAMO.

As in purely Mechanical Engineering the very best designing and workmanship may be neutralised by subsequent treatment at the scene of operations, so is it in Electrical Engineering. Too great stress, therefore, cannot be laid upon the importance of having good *foundations*, as the dynamo is a high-class piece of quick-running machinery, and unless securely fixed will injure itself by vibration, whereas, if well fixed, it should run smoothly for many years.

The foundations should be of brick, concrete, or stone, preferably the two former, with a stone about 12″ thick on the top; moreover, if brick is used, it should be built in cement. With large dynamos, the holding-down bolts should be carried to the bottom of the foundation, and properly fitted to suitable washer plates; small machines, however, only require the well-known jagged Lewis bolts let into the stone bed, and secured with lead, sulphur, or cement. It may be further noted that a good bottom for the foundation to rest on is indispensable, and if the ground is bad, the excavations must be made deep enough to ensure solidity.

In all cases it is advisable to fix the dynamo upon a sliding cast-iron bed plate, with tightening screws for taking in the slack of the belt or rope gear, but before this bed can be fixed in position, the stone on which it rests should be dressed to a true surface, as indicated by a straight edge and spirit level in the usual way.

To ensure the square setting of the machine with the fly wheel pulley of the main engines, a fine cord should be tightly stretched across the face of the wheel, and also that of the dynamo pulley, by means of which any inaccuracy will be at once detected. This, we may add, is a very popular method of fixing truly in position all kinds of gear.

Before a dynamo is ready for starting it should be carefully examined, to see that no temporary defects exist. That is, the main bearing caps should be removed, and the bearings cleaned of all dirt or grit that may have got into them during erection, then well oiled, and the caps replaced, the armature and spindle being revolved to insure their free running.

The commutator must next be examined, lest it may have sustained damage in transit, etc., and before any current is taken from the machine, it should be polished with a piece of worn emery cloth, the brushes being first raised, otherwise emery dust would get under them and cause abrasion of the surfaces.

The clean and free action of the brushes and brush holders on the spindles should then be noted, a stiff paint brush being useful for dusting them, and also for removing any brass or copper dust that might afterwards accumulate. The brushes on being lowered ought to bear on the surface of the commutator with a soft elastic pressure—if too lightly they will jump off when running and create sparking, but if too heavily they will cause cutting. It should also be noted that they bear in the right position upon the commutator, and with the correct number of copper sections between each brush.

When all these leading points, and a few more of minor nature, have been attended to, and the lubrication gear, etc., put in exact order, the machine is ready to start in unloaded condition; and after its action has been perfected, it is ready for use as a generator of electricity. This practice in dynamo erection at the site, and subsequent preparation for work, runs more or less upon the lines of all machines and engines; *electrical* machinery, however,

is so delicate in construction that extra care has to be employed to ensure success in *maintenance* as well as in working, which may be most continuously attained as follows :—

The bearings must be well oiled by means of sight feed lubricators of glass and brass, as shown in our illustrations. The commutator, which is the life and soul of the machine, should be kept in the most perfect order by means of cleaning and lubricating, and thus the dynamo will be enabled to run faultlessly for long periods. All other good machinery will do the same under similar circumstances, but if neglected there will be, in every case, heated, cut, and abraded bearing surfaces, and, to crown all, possibly a complete smash which should have been avoided.

Dynamos for electric lighting are usually constructed for an electro-motive-force of either 65 volts or 105 volts at the terminals. The former is most suitable for running arc lamps in parallel, but it also enables incandescent lamps to be run from the same dynamo, and, if necessary, on the same cables. The latter voltage is best adapted for incandescent lighting, but, where desired, two arc lamps can be run in series on the same circuit.

For electric transmission of power it is usual to increase the E. M. F. at the terminals of the dynamo, so as to reduce the cost of the conductors, and for designing purposes the amount of this proposed force must be known at the outset. For instance, an E. M. F. of 105 volts is generally found economical in collieries, where the motor is not more than 200 or 300 yards from the dynamo, as it enables incandescent lamps to be run by the same dynamo. Where, however, the distance is from 300 yards to half a mile, it is desirable, chiefly for the sake of economy in cables, to increase the E. M. F. to 300 volts. For 800

yards, and up to one mile, a maximum of 500 volts is recommended, and so on for other greater distances.

The method of finding the *Power obtained from Electric Motors* may be thus given:

The actual volts required at the terminals of a motor, to give an effective brake horse power on its spindle, depends upon the efficiency of the motor, those of small size and good construction usually having an efficiency of about 85 per cent., whilst in the larger ones as much as 90 to 92 per cent. is obtained. If, therefore, it is desired to ascertain the number of watts needed to produce effective horse power, the following rule will be of service:—

$$\text{Electrical H. P.} = 746 \times \frac{100}{85} = 877, \text{ say}$$

900 watts required at the motor terminals where the efficiency is 85 per cent., but at 90 per cent., 830 watts only are necessary. It must be noted, however, that there is a loss of voltage between the dynamo and the motor, due to the resistance of the cables.

The *volts lost in a cable of any length* may be found by multiplying the resistance of the cable in ohms by the current flowing through it, bearing in mind at the same time that the distance between the dynamo and the motor is practically doubled in the cable on account of the return conductor. If, therefore, the motor is half a mile from the dynamo the total length of the cable will be one mile.

To find the loss in volts in a $\frac{7}{15}$ cable, that is, one composed of 7 wires No. 15 Legal Standard Gauge, and one mile in length, with a current of 29 ampères—approximately 1000 ampères per square inch section of copper—the resistance of the above cable equals

$$1{\cdot}528 \text{ ohms} \times 29 \text{ ampères} = 44{\cdot}312 \text{ volts lost.}$$

It may be taken as a sufficiently accurate general rule

for ordinary practice, that there is an approximate loss of 2·5 volts per 100 yards in cables where the current density is 1000 ampères per square inch of section of copper wire.

Another useful rule for calculating the *watts lost in any length of cable*, is the following :—

First square the current, and then multiply by the resistance, which will give the watts lost in a cable, as, for example, in that of $\frac{7}{18}$ mentioned above when carrying a current of 29 ampères. That is :—

$$29^2 \times 1{\cdot}528 = 1285{\cdot}048 \text{ watts lost.}$$

It is therefore necessary in estimating the size of generator for driving a motor, to add to the actual watts required at the terminals those lost in the cables. The generator must also be constructed to give at the terminals an E. M. F. equal to the volts lost in the cable, plus the volts required at the terminals of the motor. It may also be noted that by suitably proportioning the size of the cable to the work to be done, it is possible to make the power consumed in the cables anything that may be desired, it may be added, however, that by unreasonably increasing the size of the latter, and thus reducing the loss, a point is soon reached at which the first cost becomes so great that the saving will not be economical.

The view already given on page 292 illustrates a type of machine which can be used either as a *Dynamo* or as a *Motor* as well as an *Electric Welder*, according to circumstances.

The magnets are of the horse-shoe type, and made of the softest wrought iron or mild steel, the magnet bobbin being separately wound, so that they may be easily removed if required.

The armatures for all large machines are of the improved drum type, and are designed to fulfil the require-

ments of the Admiralty and War Office as regards heating and efficiency. As has been noted, the bearings are kept very low for the sake of steadiness. The following is a table of useful sizes of machines which are generally made in large numbers, but which can be built to suit any speed or output according to requirements, the standard E. M. F. being in all cases 65 to 105.

PARTICULARS OF DYNAMO MACHINES FOR ELECTRIC LIGHTING.

Units of 1000 Watts.	No. of 16 C.P. Lamps will drive.	No. of 2000 C.P. Arcs.	Approximate Revs. per Minute.	Diameter of Pulley.	Width of Face.	Brake H.P. required to drive.
1	15	1	1500	4	3	1¾
2	30	3	1400	6	4	3½
3	50	5	1300	7	4	5
5	85	8	1200	8	5	8
6	100	10	1100	9	5	10
9	150	15	1000	10	6	15
12	200	20	900	11	7	20
15	250	25	850	12	8	25
18	300	30	800	14	9	30
21	350	35	750	14	9	35
24	400	40	700	16	10	40
30	500	50	650	16	10	50
40	650	65	600	18	11	65
50	800	80	550	18	11	80

The same engraving also represents a class of large dynamos employed for transmission of power, and provided with sliding bed plates when required so that the slack of the belt can be taken up whilst the machines are running. When used as motors above 130 horse-power, the bed

plate is extended and a third bearing fitted outside of the driving pulley to insure greater steadiness. For standard machines the following table gives the leading particulars.

LARGE MOTORS FOR TRANSMISSION OF POWER.

B.H.P.	Speed.	Current.	Terminal. E.M.F.	Pulley Diameter.	Pulley Face.
66	500	120	450	20	12
77	475	140	450	22	13
87	450	160	450	24	14
99	430	180	450	26	15
110	410	200	450	28	16
138	380	250	450	30	17
166	360	300	450	32	18
190	360	350	450	34	19
220	340	400	450	36	20
275	320	500	450	40	24

For *Incandescent and Arc Lighting* of standard speed—series, shunt, or compound wound—60 volt lamps, somewhat similar dynamos are extensively employed; but as many of the foregoing remarks equally refer to these, nothing more need be said on this point. We give, however, a useful Table that shows at a glance their leading particulars, the volts at terminals being in every case 65.

A recently designed arrangement by Messrs. Scott and Mountain, enabling a dynamo to work a vertical shaft direct, has been very successfully accomplished in numerous varied operations. In this case, the armature axis is placed vertically, and fitted with a coupling for attachment to the shaft, the commutator being located in

the upper portion of the machine, and therefore easily accessible.

Another special arrangement by the same firm is applicable to innumerable minor operations of a purely commercial, private, or domestic character, such, for instance,

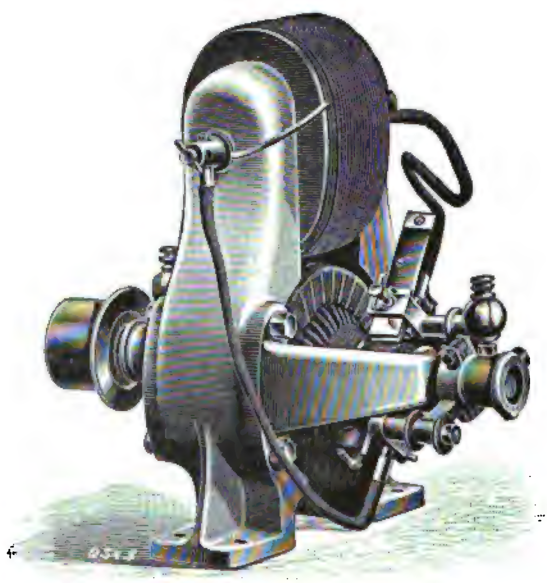
Class A.—TYNE DYNAMOS FOR INCANDESCENT AND ARC LIGHTING.

Output in Watts.	Ampères at Terminals.	Speed in Revolutions per Minute. Approx.	Diam. of Pulley.	Face of Pulley.	No. of 16 C.P. 60 Watts Incand. Lamps will feed.	No. of 2000 C.P. Arcs in Parallel.	Brake H.P. required to drive. Approx.
1170	18	1600	4	3	18	2	$1\frac{3}{4}$
1690	26	1500	6	4	26	2	3
3900	60	1400	7	4	60	6	6
7150	110	1300	8	5	110	11	10
10400	160	1200	10	6	160	16	15
14625	225	1100	11	7	225	22	21
20150	310	1000	12	8	310	31	30
27950	430	900	14	9	430	43	40
37700	580	800	16	10	580	58	55
44200	680	750	16	10	680	68	63
57200	880	700	18	11	880	88	82
65000	1000	600	20	12	1000	100	98
97500	1500	550	24	14	1500	150	140
110500	1700	500	28	16	1700	170	150
136500	2100	450	30	17	2100	210	190

as the driving of small workshops, lathes, machinery, fans, sewing machines, butter-making machines, saws for cutting firewood, and a great variety of other purposes. One of these *Small Electric Motors* is shown on the next page so clearly as to need no comment. It may be noted,

however, that although the ends of shafts usually project a little beyond the surface of a bearing to give a good finish, they here stop slightly within it, an internal groove, as shown, acting as an oil collector to aid in the continuous lubrication of the surfaces exposed to wear. This is so effectually performed that the system has become very popular.

As these motors are chiefly made in four sizes, from one-quarter of a horse power to one horse power, the scope of their application in practice will be easily understood.



SMALL ELECTRIC MOTOR.

CHAPTER XXIV.

ELECTRIC LIGHTING, ELECTRICAL MOTORS AND GENERATING MACHINERY.

Comparative Advantages and Cost of Electric Lighting and Gas—Table showing Hours of Lighting throughout the Year—Train Lighting Plant—Various Applications of Electric Motive Power—Oil Engine for Driving—Train Dynamos—Special Type of Horizontal Engine—Its Advantages—Compound and Triple Expansion Engines—One Crank Triplex Engines—Full Particulars—Universal High Speed Engine—Improved Silent Engine.

THE *Advantages and Relative Cost of Electric Light and Gas* may be thus given:—

The lighting of collieries, mills, factories, ships, and public buildings by electricity is really the best method, and, on account of its coolness and absolute freedom from dirt and smell, is far more healthy than gas, besides extensively reducing the cost of re-decoration and ventilation in any structure. It is also a great protection to the books of public libraries, whose leather bindings are rapidly destroyed by the fumes of gas, especially in the upper regions of the rooms that contain them. In factories, the health of the workpeople is much improved, and, further, an electric light installation, when properly fixed, greatly reduces the risk of fire, which in itself is of vast importance.

Owing to various circumstances, the cost of electric lighting is now much less than it used to be, but before the relative value of each system can be fairly ascertained, so

many conflicting elements have to be considered that the best statement we can now give might be so much vitiated in a short time that it is not advisable to say much on the subject. In 1896, however, an elaborate comparison of the total cost of the gas lighting and electric lighting of the city of Manchester for that year revealed the important fact that, although the installation of the latter cost considerably more than that of the former, its advantages were so great as to prodnce an excellent return for the money expended on it. So excellent, indeed, as to warrant the hope that, with future improvements in view, still more favourable results will be obtained.

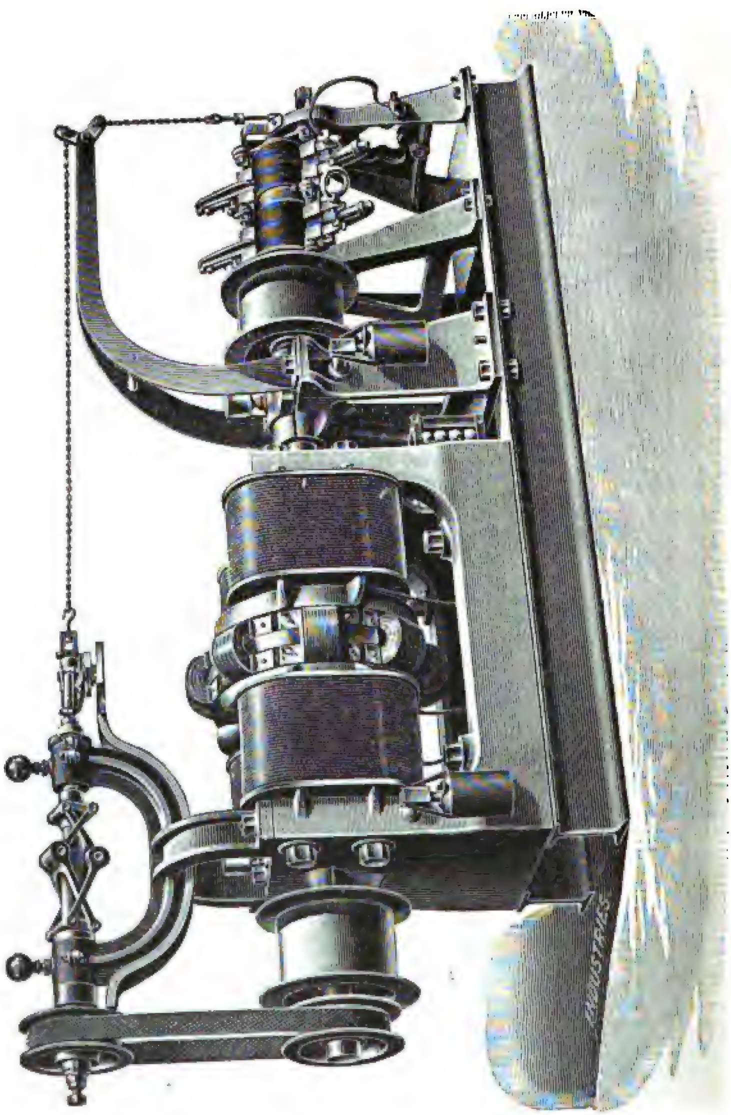
The following table will be a valuable aid when calculating the comparative cost of electric lighting and gas, as it shows at a glance the number of hours required in England for the various months, and also for a whole year of 8,760 hours.

The system of passenger train electric lighting has been tried for many years past, some of the most eminent railway authorities having given the subject great attention. The majority of the large companies were, however, in favour of gas until the Brush Electrical Engineering Company introduced a new system, which has been very successfully adapted to the varied requirements of railway practice, and which we indicate by the engraving of their *Train Lighting Plant* shown on page 434.

Many difficulties have arisen in practice with this plant, owing to the peculiar conditions of railway transport, first-class carriages being easier to work than those which are more frequently separated from each other. This rendered it necessary that a reservoir of electrical energy should be provided for each of the latter sufficient to last for eight or ten hours, which of course has been a serious obstacle.

TABLE SHOWING HOURS OF LIGHTING THROUGHOUT A YEAR OF 8760 HOURS.

Daily Lighting.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Total per Annum.
From sundown to 8 p.m.	125	89	67	36	6	—	—	21	54	87	117	140	742
„ „ 9 „	156	117	98	66	37	20	25	52	84	118	147	171	1091
„ „ 10 „	187	145	129	96	68	50	56	83	114	149	177	202	1456
„ „ 11 „	218	173	160	126	99	80	87	114	144	180	207	233	1821
„ „ midnight	249	201	191	156	130	110	118	145	174	211	237	264	2186
„ „ 2 a.m.	311	257	253	216	192	170	180	207	234	273	297	326	2916
„ „ 4 „	373	331	297	276	254	230	242	269	294	335	357	388	3646
„ 4 a.m. to sunrise	125	92	69	32	3	—	—	24	51	75	103	154	728
„ 5 „ „	94	64	38	2	—	—	—	—	21	44	73	123	459
„ 6 „ „	63	36	7	—	—	—	—	—	—	13	43	63	225



ELECTRICAL TRAIN LIGHTING PLANT.

Originally, the dynamo was driven by belting from one of the axles of the van in which it was placed, but it was found very difficult at first to obtain a constant electromotive force by this arrangement, owing to the great variation in the speed of the train, and also to its reversed motion from time to time. These points received special attention from many engineers, some of whom made important improvements in this matter.

The Brush Company has during the last few years so matured the system, as to have supplied for train lighting purposes a large number of dynamos similar to that shown in the view. Here, the whole of the gearing is automatic in its action. Two flanged pulleys are keyed upon the armature shaft, and these are driven by belting from two similar pulleys upon one of the axles of the guard's van. Jockey pulleys are also provided in order to obtain the necessary tension for driving. While the train is at rest, the brushes are kept entirely free from the commutator, and if any light is required in the train, the current is supplied from the accumulators which are placed in the van. When the train starts, the brushes are brought automatically to their correct position upon the commutator, by means of a special lever arrangement enclosed in a box at the end of the armature shaft. At the same time, connections are made so that a current passing round the coils of the field magnets would give them the polarity to suit the direction of rotation of the armature.

A centrifugal governor is driven by a small belt from the armature shaft, and when the speed of rotation attains 500 revolutions per minute—equivalent to a train velocity of from eight to twelve miles per hour, according to the relative sizes of the wheels and pulleys—the action of the governor closes a circuit from the accumulators through a

relay, and the latter completes the circuit to the field magnets, and allows the cells to excite the field.

As soon as the field magnets are fully excited, the charging circuit is closed by means of an automatic switch, and the dynamo begins to charge the cells. At the same time a small resistance is inserted in the lamp circuit to compensate for the difference of potential between the mains while the cells are being charged. An electromotive force of 2·5 volts is needed for this purpose, but as the cells, when discharging, give only 2 volts each, it is obvious that if the lamps were switched on first while the train was standing in a station, there would be a very noticeable increase in illumination as soon as it attained a speed of, say, twelve miles per hour; indeed the drop in the light is very considerable in some trains when slowing down to enter a station.

From its initial charging speed, the above dynamo practically maintains a constant electromotive force up to the highest velocity attained by the train, the usual range being from one to three. That is to say, it will begin to charge at a certain speed, which is about one-third of the maximum. The figures on opposite page give the results of tests made upon this machine, which may be considered very satisfactory.

The dynamo occupies a space of about 6′ 0″ by 1′ 6″, the commutator being in two parts, as is usual with the Brush machines. Twenty-four cells, of the E.P.S. type, are generally installed in the guard's van, each of which has a storage capacity of 500 ampère hours, and weighs 228 lbs. There is also placed in the guard's van a voltmeter, ammeter, and other suitable instruments.

So fully have Messrs. Hornsby & Sons recognised the great advantages of electric lighting for trains, that they

have designed a special arrangement in which their own *Oil Engine* forms the motive power. For almost every purpose, as well as that of train lighting, this engine has proved most acceptable, as it is very simple, economical, and easily managed.

On lines of railway, electrical motive power has proved so useful that it is coming rapidly into favour in connection with *Lifting and Hauling* appliances, many of which have been successfully employed in large warehouses, and

TABLE OF THE RESULTS OF TESTS WITH TRAIN LIGHTING PLANT.

Revolutions.	Volts.	Ampères in Lamps.	Total Ampères.
1420	57	50	65
1000	57	50	62
875	57	50	59
620	56	49	56

At 520 revolutions Dynamo automatically cut out.

especially in those where the insurance offices would not allow the employment of steam cranes on account of the fire risk. With Messrs. Crompton's *Travelling Jib Cranes* of this nature, the current is supplied to two conductors, running between the rails on insulators, and passed up through the base plate to the motor by means of suitable spring buffers and circular contact paths. This latter drives the whole of the motions of the crane, namely, hoisting, travelling, and slewing, by means of very compact

gear. So efficient is this system that there is no difficulty in dealing with much heavier weights when required.

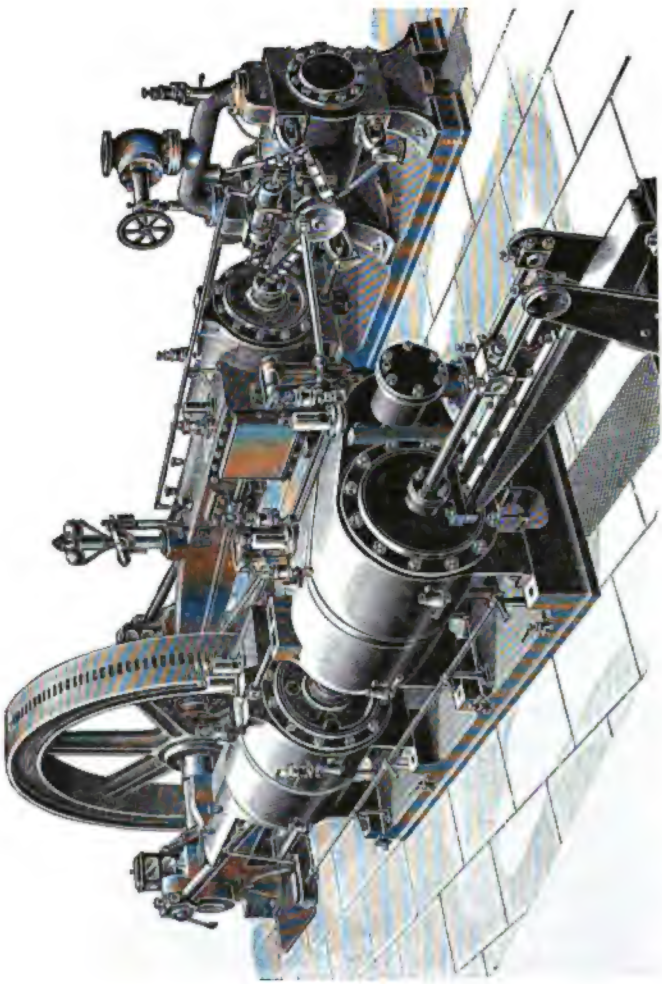
Having noted a few of the leading particulars of electrical machines and their uses, let us now examine the peculiarities of their *Driving Engines*, those, at least, that, while quite suitable for other occupations, are specially adapted for dynamo working either on a large or on a small scale.

Firstly, then, we have the horizontal class of machinery which is doing immense service on the grandest scale of electric light installations, and for supplying electricity to motors for works, one set of which, of the very popular Surface Condensing Triple Expansion type, by Messrs. Hick, Hargreaves & Co., is shown on the next page. Here a high pressure cylinder, 13″ diameter, and a low pressure cylinder, 21″ diameter, work one crank in tandem fashion, whilst a duplicate of the latter, and an intermediate cylinder, 20″ diameter, are similarly connected to the other crank, the stroke of all being 3′ 0″, revolutions 80 per minute, and steam pressure 160 lbs. per square inch.

The valves to each cylinder are respectively of the Corliss, piston, and slide description, to suit the different steam pressures, the intermediate cylinder tail rod and connections being used for working the air pump, which, with the Condenser of marine type, are conveniently placed below the floor.

This machinery is doubly interesting from the fact that while the two right hand cylinders illustrate a single high and low pressure tandem engine, which could be easily made suitable for electric or general purposes, the whole in combination shows a set of motors which have proved so economical from every point of view that many of

them, sometimes with Corliss gear throughout, have been constructed up to 4,000 horse power by the above firm.



HORIZONTAL TRIPLE EXPANSION ENGINES, 325 HORSE POWER.

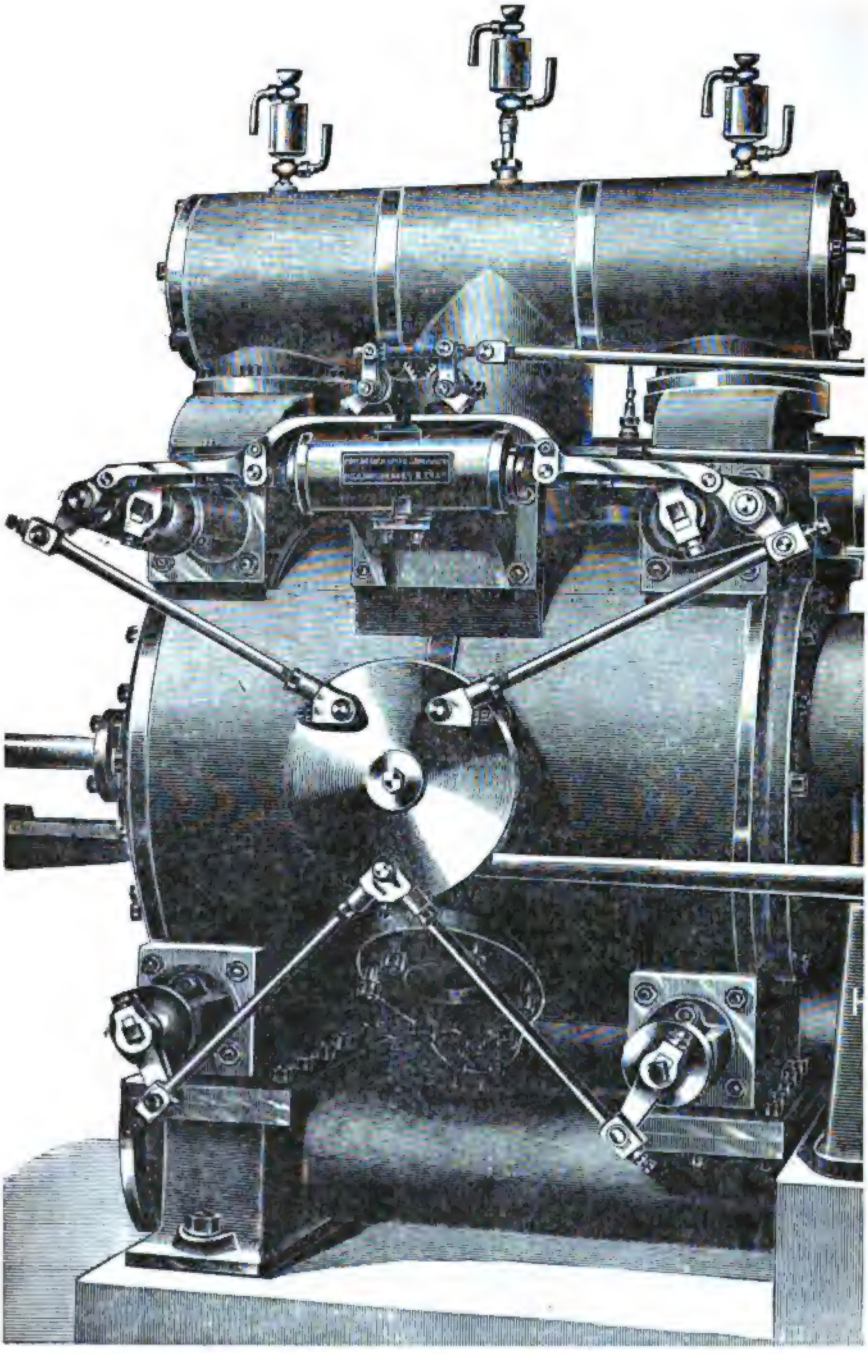
These, being highly finished, produce a very striking effect when placed in position in the engine house.

As the last named gear is not so much appreciated in some parts of the world as its special merits fully entitle it to be, we give on next page a detail view of a portion of one of the main driving engines built by the same firm for the very recent Electricity Works at Leicester. This, in conjunction with the previous plate, will form an admirable study in design and detail construction, the former of which has been already referred to.

As will be noted in the general view the cranks are of the universally popular solid slab and easily forged marine type, their sides being planed and beautifully polished, and their edges slotted and then milled to perfection, thus ensuring economy combined with excellence in production. Two kinds of main connecting rods are chiefly used for large and small engines on land and sea. One of these is of the Tee-headed "John Penn," and the other of the still better "Maudslay" type shown in the plate, everything about it being easily machined and finished, the bolts being also better steadied than in the former case, and the rod end more handsome in appearance.

Coming now to the detail view, we have another field of observation before us. If both ends of a rod are exactly alike, the distance between their centres must either increase or decrease as their bearings wear down. In those which work the valves under review this evil is avoided by means of a very simple adjusting arrangement which ensures exact motion of the valves, the rods being very light owing to the equilibrated nature of the valves they actuate.

Amongst vertical engines those of the *Central Valve* order, by Messrs. Willans & Robinson, are very extensively applied to Electrical work. Here, there is no working part visible, as the outside casing covers a very simple arrangement of details, which in unique fashion performs



CORLISS VALVE GEAR FOR MAIN DRIVING ENGINES.

all that is required in the most efficient manner. These details include the usual high and low pressure cylinders if compound, and high, intermediate, and low if triple expansion, placed over each other in tandem fashion, and with as little space as possible between them.

Instead of piston rods we have trunks, to which each piston is bolted, the lowest of all having a cylindrical guide attached. The trunks contain the piston valves, which, from their central position, give the engines their distinctive title, and these valves are so worked by one eccentric to each engine as to allow the proper admission and exhaust of the steam to or from each cylinder, thus producing the most perfect action in the machinery without the aid of any other gear than two connecting rods to each crank pin, the solid forged eccentric being placed between them on the pin, and not on the shaft.

The above is a single acting engine, having all its working parts constantly in compression to enable it to run at high speed with the greatest smoothness, the bearing brasses being kept steadily in contact with the shaft or pin, their condition at any time being easily ascertained upon removal of the outer doors, which are common to all closed-up engines.

Another secret of successful action is the self-lubricating principle, which this style of framing readily admits of, the bottom forming a tank containing the best castor oil, into which the crank gear so splashes as to keep the main working parts continually lubricated by the spray thus created.

These engines may be either single, double, and treble compounds, or similarly treated triple expansions up to 900 horse power, the tandem arrangement being invariably adopted. They may also be coupled direct to the dynamo,

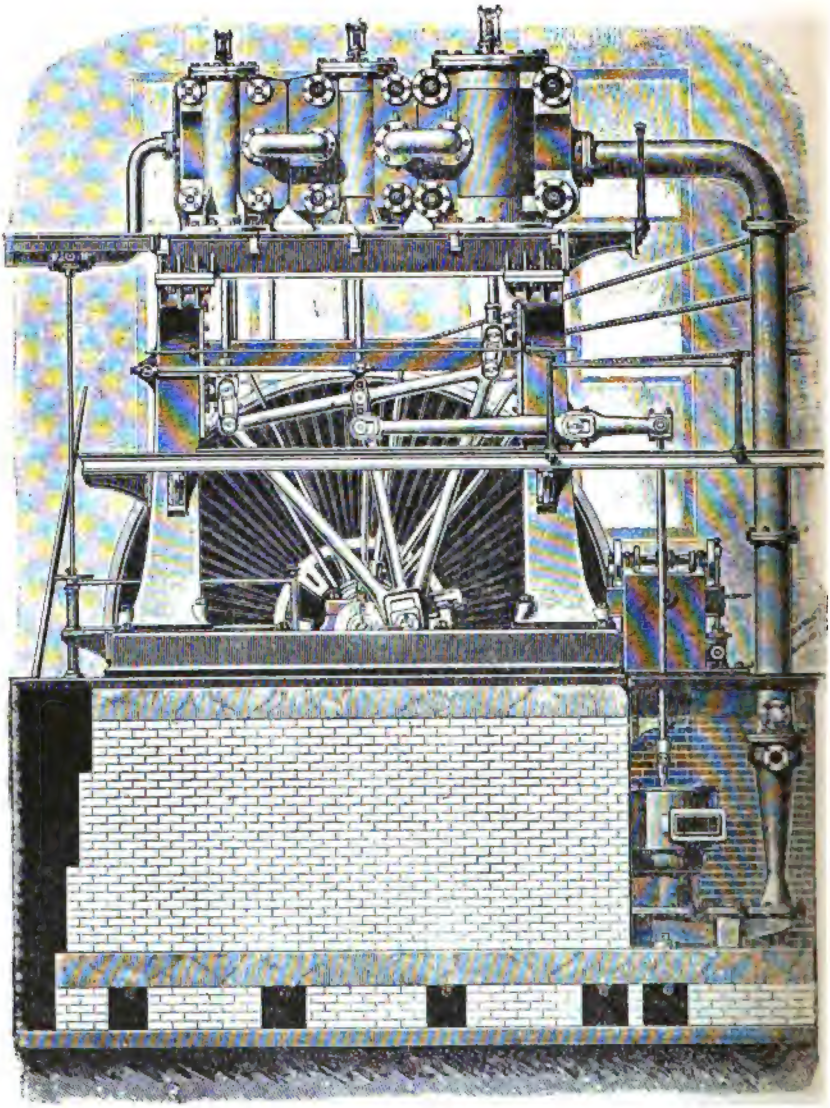
or the latter may be belt- or rope-driven from the fly wheel, according to circumstances. It may be added that the usual steam pressures are as follows:—For single cylinder engines 60 to 90 lbs. per square inch; for compounds 90 to 160; and for triples 170 to 200 lbs.

The plates on two following pages represent another peculiar type of modern *Vertical Triple Expansion Engines* which perform good, steady, and economical main driving. These engines, in quadruple form, were originally designed by Messrs. Fleming & Ferguson for marine purposes, where they gave so much satisfaction that Messrs. John Musgrave & Sons introduced them as mill engines, and now make them up to 5,000 horse power, and 240 lbs. steam pressure. In each case the cylinders are placed in pairs, on each side of the crank shaft, to the two pins of which they are linked by means of triangularly framed connecting rods that allow of no dead centres.

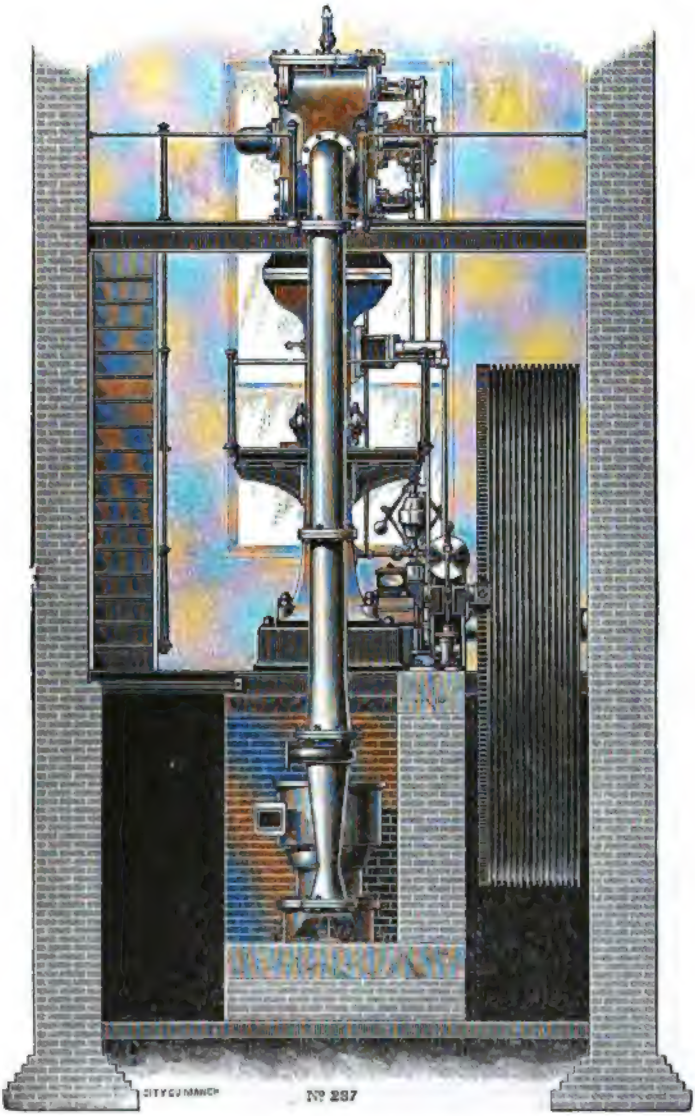
The end elevation of the Triple Engines, as well as their side elevation on page 445, not only show clearly the arrangement as a whole, but also a portion of the engine-house, with foundations and holding-down bolts, platforms, and staircase. Besides these, the cylinders with their Corliss valve arrangements, triangular connecting rod, grooved fly wheel and rope gear, and air pump on low level, etc., can be clearly seen.

As the machinery has to be moved slowly from time to time when not under steam, so that it may be kept in good order, barring or turning engines as shown are employed, the object of which is to so act upon the large spur wheel as to produce the desired effect, and when not required to become disengaged.

The main peculiarities of these engines are, firstly, the triangular connecting rod, and secondly, the fact that only



ONE CRANK TRIPLE EXPANSION ENGINES--END ELEVATION.



ONE CRANK TRIPLE EXPANSION ENGINES—SIDE ELEVATION.

one crank is used for the three cylinders, which makes an extremely compact arrangement. While, in marked distinction to the ordinary single crank engines, the above can be easily started at any point of a revolution. The following leading particulars may be useful in reference to the engines shown in the plates, with the results obtained in regular working.

Leading Dimensions of Vertical Triple Expansion Engine.

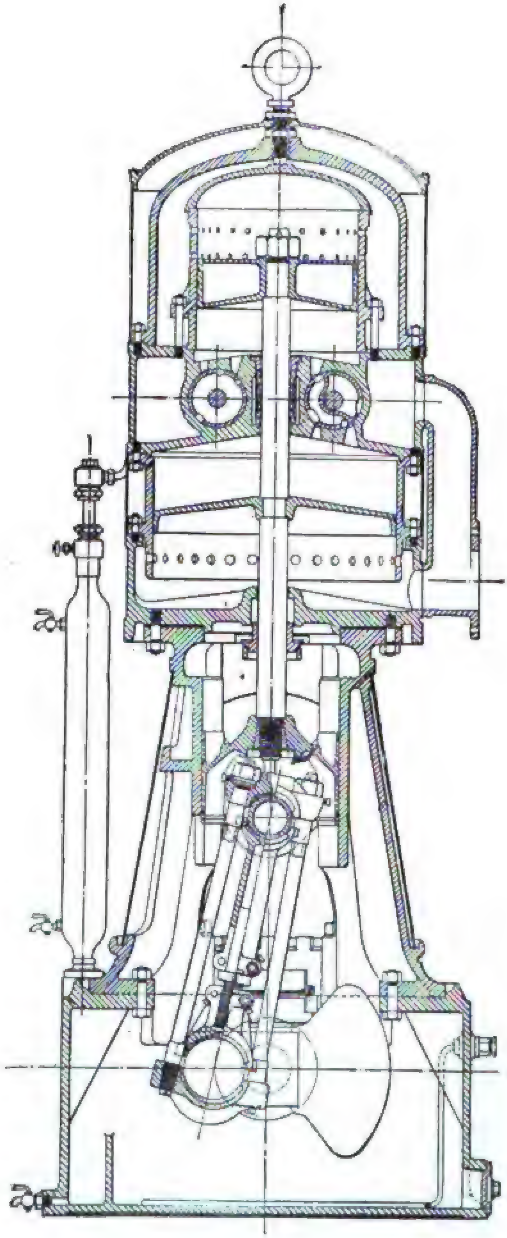
Diameter of High-pressure Cylinder ...	16"
Diameter of Intermediate Cylinder	26"
Diameter of Low-pressure Cylinder ...	42"
Stroke of Pistons	4' 6"
Revolutions per minute	70
Diameter of Steam Pipe	6"
Type of Boiler used ...	Lancashire Two-flue
Number of Boilers in use	2 (1 spare)
Diameter of Boilers	7' 6"
Length of Boilers	30' 6"
Total Grate Surface in use	72 sq. feet
Total Heating Surface in use	1678 sq. feet
Kind of Mechanical Stokers used ...	Proctor's
Height of Chimney	158' 0"
Internal Diameter at Base	5' 0"
Average indicated Horse-power	741
Coal per week for Engine only ...	27 tons
Price of Coal per ton	9/11
Running Time per week	56½ hours
Boiler pressure (ordinary)	160 lbs.
Vacuum	13¾ lbs.
Temperature of Injection Water ...	65° F.
" " Feed to Economisers	80° "

Temperature of Water entering Boilers	240° F.
„ „ Gases „ Economisers	645° „
„ „ „ leaving „	235° „
Coal for Engine per I. H. P. per hour	1·44 lbs.
Cost of Coal for Engine per 1000 H. P. hours	6/4½
Proportion of Grate to Heating Surface	1 to 23·2
Coal burned per sq. ft. of Grate Surface per hour, about	16 lbs.
Coal burned per sq. ft. of Heating Surface, per hour, about...	0·7 lbs.

One of the most novel as well as most practical motors of to-day is the Raworth *Universal High Speed Engine*, shown on next page in transverse section. This engine may be compound tandem, as illustrated, or triple or quadruple expansion, etc., according to requirements, and contains many novelties in design which are so clearly visible in the drawing as not to need much description. It may be noted that—through the inlet pipe at the back of the engine—the left hand Corliss valve admits high pressure steam underneath the upper piston, and, when this has approached the top of its stroke, the vapour exhausts through the lower ring of holes on the cylinder into the surrounding receiver.

At the commencement of the down stroke, the steam in the latter and also in the upper portion of the high pressure cylinder, acts on the top of the low pressure piston, free exhaust being obtained by means of a ring of holes as before, and by the opening of the exhaust valve. With triple expansion engines, one high pressure and one intermediate cylinder are placed tandem fashion over one crank, two low pressure cylinders being placed over another crank, quadruples being similarly arranged in pairs.

The pistons are held fast in position by a tube, which



UNIVERSAL HIGH SPEED ENGINE.

embraces the piston rod, and is screwed hard up by the nut at the top end. The crosshead guide is cylindrical. The connecting rod is in two separate parts, the outside rods taking all the tension, and the internal strut all the compression in working, the latter being provided with a screw adjustment, by means of which any slackness can easily be rectified.

For lubrication purposes a portion of the bed plate is formed into an oil tank for the cranks to dip into at each revolution, and as the engine is closed in, the lubrication of all the adjacent working parts is automatic. The main bearings, governor gear, and some of the other details are, like the others, more or less novelties that work well and economically, and deserve careful study. The last noticeable feature is that *lathe work* is almost entirely employed throughout, and that the motor can be used very successfully for dynamo driving, mill driving, pumping, marine propulsion, and other purposes.

A recently-improved engine, by Messrs. Bumsted & Chandler, is of the triple expansion, one crank type, the three pistons being attached to one rod which, at its lower end, is secured to a cylindrical crosshead. The valves are of the piston class, similarly mounted, worked by one eccentric, and so arranged to admit and release steam to and from each cylinder that the connecting rod is always in compression, thus producing silence in working, as all slackness at the main bearings is avoided. To increase the efficiency of the automatic lubrication, splashers are attached to the crank webs, which throw the oil to the top of the casing in which the main working parts are located, and this, in connection with the other leading features referred to, has made the engine one of the most useful of the present day.

CHAPTER XXV.

WATER TUBE BOILERS FOR ELECTRICAL WORK.

The Water Tube Boiler System — Disastrous Failures of other Boilers — Water Tube Boilers of the Past — Improvements — Detailed Description — Action of the Boiler — Advantages of the System — Absence of Riveted Joints — Perfect Combustion — Quick Steam Raising — Freedom of Expansion — Supreme Safety — Accessibility for Cleaning — Convenient Transportation — Simplicity of Manufacture — Gradual Increase of Steam Pressures — How Expansion of Steam affects size of Boiler — Table of Steam used Expansively — How Increase of Pressure improves Fuel Economy.

NOTHING, perhaps, of late years has created more discussion in the shipping world than the *Water Tube Boiler* system, which not only affects the full economy and weight of a ship, but her safety, and also the space available for other purposes. The question has, one would think, been pretty well solved by the matured practice of the last few years, but there is still much to be done before perfection is arrived at. On land the case is different, as the conditions are to a large extent altered, although the grand leading principles remain unchanged, the most important of all being the fact that a boiler thus constructed is practically freed from the danger of disastrous explosion, even under much higher pressures than those of about 250 lbs. per square inch to which we have now reached.

This will be fully apparent when we contrast the harmless result of failures in the above with the sometimes dreadful explosions of others. Take, for example, the bursting of 22 boilers in one range in Upper Silesia, in

1887; 27 out of a battery of 36, at Shamokin, U.S.A., in 1894; 11 out of 15 at the Warrenby Iron Works, England, in 1895, not to mention innumerable other cases where one or more boilers have exploded with very destructive results to life and property.

Water Tube Boilers date back to the earliest days of the steam engine, the first of this class on record having been made in the year 1766, but it was too crude an attempt to do anything more than originate the scheme. In 1788, an American inventor patented a plan of his own which was a step in advance, but in 1805 another American, John Cox Stevens, designed and made a boiler on this plan, which was employed in a Hudson River steamboat. Its prosperity, however, was ephemeral.

Other inventors introduced numerous innovations from time to time. All sorts of plans and arrangements were worked out with large tubes and small tubes, straight ones and curved ones, and diagonally and horizontally-fixed tubes, etc. Every kind of scheme was tried, approved of at first, and subsequently condemned because practically faulty. All this, and very much more, was done up to the year 1856, when Mr. Stephen Wilcox, of New York, made so important an improvement as to lead to the successful introduction, in 1867, of the well-known Babcock & Wilcox boiler.

None but those in the secret have any idea of the immense difficulties—commercial and technical—that have beset the introduction of many good inventions—inventions, too, that are now of universal application, and a source of wealth to nations. Inventions whose originators struggled, persevered, spent all their means in fruitless efforts to perfect, and at last died in poverty; whilst those who followed them reaped substantial benefits. It was so

with Mr. Hall, whose surface condenser system for marine engines has long been indispensable; with Mr. Richard Roberts, of textile machinery fame; and many others too numerous to mention. Beyond all, perhaps, were the inventors and improvers of the sewing machine, which, through a long series of failures, required a hundred years to bring to its present excellence.

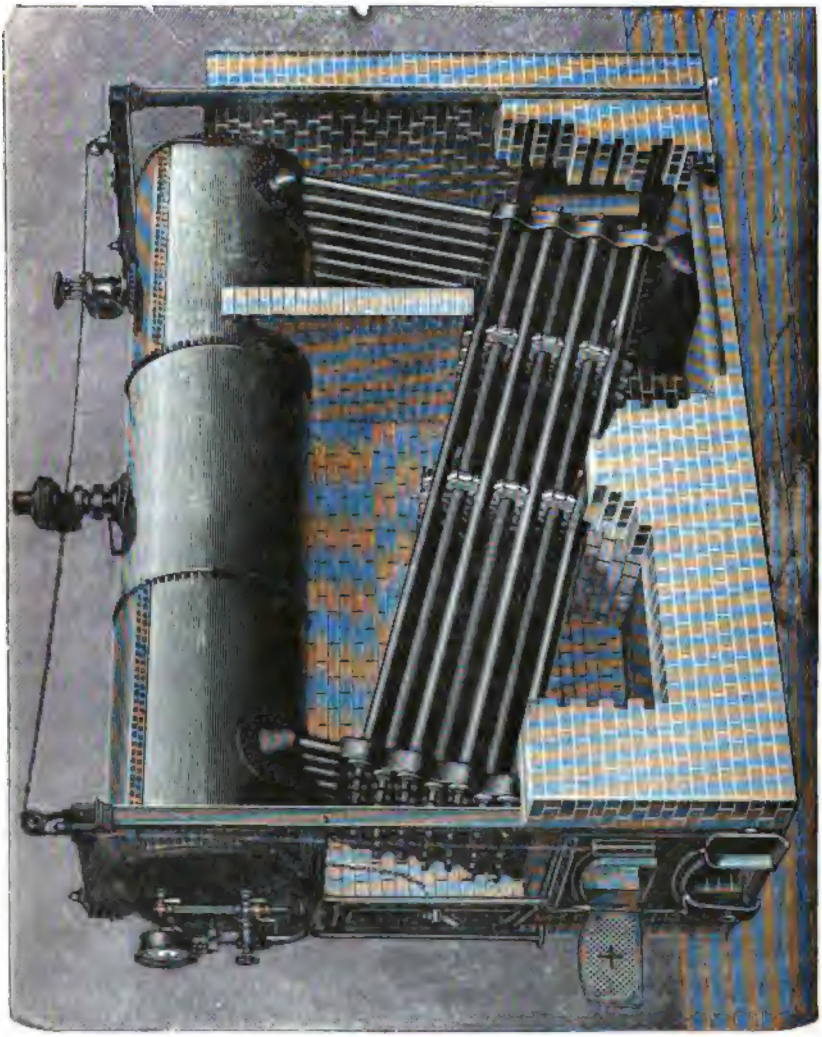
The history of water tube boilers contains much that is romantic and disappointing, but of these, as of all other famous inventions, it may be said that as plan after plan was approved of, temporarily discarded, and finally matured, their future success lay entirely in the hands of the mechanical engineer who could design and arrange their details to the best advantage.

The adjacent Plate will clearly illustrate the construction of Messrs. Babcock & Wilcox's boiler of to-day. As will be seen, the fabric is composed of lap-welded wrought iron tubes placed in an inclined position, and connected with each other and with a horizontal steam and water drum by passages at each end, whilst a mud drum connects the tubes at the rear and lowest point of the boiler.

The *End connections* of these tubes are in one "header" for each vertical row, the holes through which the above are passed being slightly tapered, and the tubes fixed therein by means of an expander.

The *Openings for cleaning*, opposite the ends of each tube, are closed by hand-hole plates, which are held in place by wrought iron clamps and bolts. These are tested, and made tight, under a hydraulic pressure of 300 lbs. per square inch, metal to metal, without any intervening perishable packing.

The *Steam Drum* is made of mild steel plates, double



WATER TUBE BOILER—LONGITUDINAL SECTION.

riveted to suit any desired pressure, but, unless otherwise specified, it is always tested to 200 lbs. per square inch.

The *Mud Drum* is a cylinder of cast iron, as this material is best able to withstand corrosion, and is provided with ample means for cleaning.

The *Tubes* are fitted in zigzag rows, so that the heat may be more readily absorbed than if they were placed over each other, as in cylindrical boilers. The connections between the former and the steam drum are composed of other tubes, which are attached to suitable projecting pieces riveted to the under side of the steam drum. It will be noted that the whole of the water tubes and their connections are entirely suspended from the drum, which, with all its attachments, are in turn independently slung from wrought iron girders resting on columns built into the brickwork. This arrangement avoids any straining of the boiler from unequal expansion between it and the enclosing walls, and permits the brickwork to be repaired, or removed if necessary, without in any way disturbing the other parts.

The combined Sectional and End Elevation shown in the Plate represents a type of boiler which, in various sizes, is now extensively employed for electrical and other purposes. In this view, not only are the details we have described clearly delineated, but several others as well, including the various mountings and fittings. The brickwork, too, shows the space for the furnace, from which the heated gases pass through the first portion of the tubes to the combustion chamber above, then downwards between the next portion of the tubes, and lastly, fill the back end of the boiler, the gases and smoke finally passing through the flue to the chimney. We may here observe that in brick constructions, thicknesses of

walls are given not so much in inches as in one brick, one and a half, two, etc., bricks, simply because the latter are usually made to the standard dimensions of 9″ by $4\frac{1}{2}$″ by 3″. Hence, if the number of bricks in a given space is counted, and, say, $\frac{1}{4}$″ allowed for each joint, the desired dimensions will be approximately found.

Upon lighting the fire in the furnace of the boilers, the water inside the tubes rises towards their higher end, and is converted into steam, a mingled column of steam and water rising through the short vertical passages into the drum above the tubes, where the steam separates from the fluid, which flows to the rear, and down again through the tubes in a continuous circulation. As all the passages are large and free, this circulation is very rapid, carrying away the steam as fast as formed, and supplying its place with water. It also causes the heat of the fire to be absorbed to the best advantage, thus creating a thorough commingling of the water throughout the boiler, and a consequent equalisation of the temperature, all of which prevent, to a great degree, the formation of deposits upon the heating surfaces by sweeping them to the mud drum, from which they are blown off. The pure steam is taken out at the top of the steam drum, near its back end, by means of a stop valve, and then led as directly as possible to its destination.

The *Advantages* which this class of boiler possesses over others may be thus described :—

The thick plates necessarily used in the furnaces of ordinary boilers not only hinder transmission of heat to the water, but admit of overheating, and even burning, on the side next the flame, thus producing loss of strength, cracks, and consequent tendency to rupture, which is well known to be the direct cause of most explosions. Water tubes,

however, are of such thin material that the heat is so rapidly transmitted to the fluid they contain, that even the fiercest fire cannot injure the surface so long as it is covered with water.

Riveted Joints, with their double thickness of metal in parts exposed to the fire, sometimes give rise to serious difficulties. Being the weakest parts of the structure, they concentrate upon themselves all the strains caused by unequal expansion, thus giving rise to frequent leaks, and sometimes to actual rupture. The joints between the tubes and their end plates also give much trouble when exposed to the direct action of the flame, as in tubular boilers. These difficulties are completely overcome by the use of lap-welded water tubes, which present an unimpaired surface throughout.

The *Draught Fire Tube Area*, in ordinary boilers, is limited to the actual area of the tubes. In the boilers under review, however, as will be noted, the whole of the chamber in which the tubes are enclosed gives ample time, during the passage of the heated gases to the chimney, for thorough absorption of their heat.

The *Perfection of Combustion* depends upon a thorough mixture of the gases evolved from the burning fuel with a proper quantity of atmospheric air, but this perfect mixture rarely occurs in common furnaces, as has been proved by chemical analyses, and also by the escape of smoke upon the introduction of any smoke-producing fuel. Even when smoke is not visible, a large percentage of combustible gases may be escaping into the chimney in the form of carbonic oxide or half-burnt carbon. Numerous attempts have been made to cure this evil, by admitting air into the furnace to burn the smoke, but although this may allow enough air to mingle with the smoke to render it invisible,

and simultaneously ignite some of the lighter gases, it, in reality, does little to promote combustion, while, at the same time, the cooling effect of the air more than overbalances all the advantages resulting from the burning gas.

The analyses of gases from various furnaces show almost uniformly an excess of free oxygen, proving that sufficient air has been admitted to them, but that a more thorough *mixing* is required. It may therefore be said that every particle of gas evolved from the fuel should have its equivalent of oxygen, while hot enough to combine, in order to be effective. In the above boiler the currents of gases, after leaving the furnace, are broken up and thoroughly mingled by passing between the zigzagged tubes, and have thus an opportunity of completing their combustion in the triangular chamber between the top of the tubes and the steam drum. That this is really the case has been confirmed by scientific analysis, and further, it has been experimentally proved by Dr. Alban, of the U.S. Navy, that a given heating surface, arranged as described, has 30 per cent. more efficiency than when in the form of fire tubes as usually employed.

Quick Steam Raising is here amply provided for, the water being divided into small streams, which are enveloped by thin tubes that pass through the hottest part of the furnace. Steam may be thus rapidly raised at starting, and sudden demands upon the boiler may be met by a quickly increased efficiency.

As a very practical illustration of this from another source, it may be mentioned that during a recent prolonged discussion upon the merits and possible disadvantages of water tube boilers in great naval ships, many valuable hints were thrown out. Amongst others who gave their

opinions from practice was Mr. Walter Maudslay, who stated that while it required from 12 to 18 hours to raise steam in cylindrical boilers to 180 lbs. per square inch, the same operation could be performed in their own "Bellevilles" in less than one hour.

The large *Disengaging Surface* of the water in the drum, together with the fact that the steam is delivered at one end and taken out at the other, secures in the Babcock & Wilcox boilers, even when they are forced to the utmost, a thorough separation of the steam from the water. Generally speaking, tubular boilers make more or less wet steam through priming; hence, various corrective arrangements have been introduced from time to time, none of which, however, is necessary in those we are describing, the ample passages for circulation helping to produce a steadiness of water level not surpassed by any boiler.

So far as *Freedom of Expansion* is concerned, this most desirable end is fully obtained by means of the triangular and suspended arrangement of parts, which forms a flexible structure that allows any member to expand without straining adjacent ones. This is of great importance, because the weakening effect of strains due to unequal expansion between rigidly connected details is a prolific cause of explosions in ordinary boilers. The rapid circulation of the water, however, in this case, by keeping all the parts at the same temperature, prevents to a large extent this destructive force from possibly arising.

The *Safety from Explosion* of these boilers is not only due to the foregoing precautions, but also to the division of the water into small masses, which prevents seriously destructive effects in case of accidental rupture, the comparatively small diameter of the tubes securing, even with thinness of material, great excess of strength over any

pressure which it is desirable to use. So quick, however, is the circulation of the water that no part can be uncovered to the fire until the quantity in the boiler is so far reduced that if overheating did occur no explosion could result.

Proper capacity is another most important feature in these or any other boilers, since upon it depends in a great degree their satisfactory performance. Unless sufficient steam and water content is provided there will not be regularity of action. The steam pressure will suddenly rise and fall, the water level will be subject to frequent and rapid changes, and if the steam is drawn suddenly from the boiler wet steam will result.

Water capacity is of more importance than steam space, owing to the small relative weight of the steam. *Twenty-three* cubic feet of steam space or one square foot of water space, are required to supply *one horse power for one minute*, the pressure in the meantime falling from, say 80 to 70 lbs. per square inch. The value of large steam room is therefore, as a rule, unduly overrated, but if, on the other hand, it is too small, the steam in passing off will sweep the water with it in the form of spray. Too much water space makes slow steaming and waste of fuel in starting, but an excess of steam space adds to the radiating surface and increases the loss from that cause.

The *Proportions* of the above boilers have been adopted, after numerous experiments with those of varying capacity, which have proved that this boiler can be driven to the utmost, without the slightest disadvantage. As will be seen from the engraving, the heating surface is of the most effective character, so effective indeed, that with good fuel these boilers frequently greatly exceed their rated power, whilst the space occupied, including brickwork setting, is

equal to only two-thirds of that required for tubular boilers of the same power.

Accessibility for Cleaning is another point of vital importance which here has been fully secured. Hand holes, with metal joints opposite each end of each tube, permit access for cleaning, and a man hole in the steam and water drum, and hand holes in the mud drum, are provided for the same purpose. All portions of the exterior and interior surfaces are similarly accessible, whilst the occasional use of a steam india rubber hose pipe, operated through doors in the side wall, will keep the tubes free from soot, and in the best condition for receiving the heat of the furnace.

In all engineering structures *Easy Transportation of details* is of great importance, especially in out of the way localities, hence any arrangement which enables this to be most conveniently accomplished is very desirable. As the above boilers are made in sections capable of being readily put together at any time, their carriage becomes quite an easy matter, thus rendering them capable of employment in places practically inaccessible to others. They can also, when required, be made in pieces small enough for mule transportation through a difficult country.

So far as *Repairs* are concerned, few at any time are needed, but when they become necessary, any good workman can make them, and should a tube become damaged, a spare one may be easily put in its place, the only special tool required being an expander.

The plate we have given so illustrates the foregoing remarks, that from a constructional point of view nothing more need be said. It may be noted, however, that the end boxes for each vertical row of tubes, are in one piece quite detached from the others, the hand hole covers for cleaning purposes being fixed in position by means of

one clamping bolt and small internal bridges. The gauges, pipes, and other mountings, need no comment, neither do the other parts, as the view is so complete.

A most important feature in these boilers, not yet touched upon, is their extreme simplicity of manufacture, since, with the exception of the steam drum, there is none of the costly work usually to be found in cylindrical steam producers, as may be seen at a glance.

"When I was a lad," 25 lb. steam was the order of the day, and 30 lbs a curiosity, in the engines of the period. When the compounds came in with a rush in 1868, the pressure suddenly rose to 60, and then went on to 90 lbs. Ultimately the triples raised it to 150 and 160 lbs., and with the quadruples that followed, 180 to 200 lbs. was considered quite the proper thing. With these facts before us, we may ask if the working pressure of steam has advanced from, say, 30 lbs. in 1860, to 200 in 1890, what is it likely to be in 1920, with water tube boilers capable of standing very much higher pressures than we now have? "But," some may ask, "what advantage do you gain by using such pressures?" To this we reply, "*economy*, both in engine and boiler working," as we hope to show.

Since the year 1870, a more intimate knowledge of the action of steam in a cylinder has resulted in the employment of higher pressures in order to obtain a greater saving in fuel. At that time, land boiler pressures ranged from 50 to 70 lbs. per square inch, and a single cylinder engine expanding this steam four or five times, proved so efficient that an additional cylinder was not considered necessary, but with the augmented pressures that soon followed, economy was expected from an increased number of expansions. It was discovered, however, that with these pressures a greater number of expansions than five

or six in one cylinder was not advantageous, and as marine compound engines were already in use, their adoption in a modified form for land purposes at once dispelled the difficulty. To show how the expansion of steam in a cylinder helps to regulate the size of a boiler let us take the following example:—

If an engine employed full steam in its cylinder during a *whole* stroke, or say 10 cubic feet, at boiler pressure, it is evident that if the steam were cut off at *half stroke*, only 5 cubic feet would be needed, and this quantity would gratuitously give out during the rest of the stroke a large amount of useful effort by means of its expansion. If, moreover, the steam were cut off in the cylinder at *one fourth* of the stroke, the demand on the boiler would be correspondingly reduced, and so on for other degrees of expansion as the following table will show in reference to horse power capacity for each point of cut off.

TABLE SHOWING THE THEORETICAL POWER DUE TO THE USE OF THE SAME QUANTITY OF STEAM WHEN USED UNDER DIFFERENT RATIOS OF EXPANSION.

POINT OF CUT-OFF.	Number of Expansions.	Horse-Power.
Full Stroke	0	100·0
1/2 "	2	169·3
1/4 "	4	238·6
1/6 "	6	279·1

From this it will be noted that by working the steam under six expansions, an advantage equivalent to 179·1 per cent. is derived from the same steam above the result obtained during the full stroke of a non-expansive engine.

Another view of the benefit derived by the use of expanded steam will be clearly intelligible when it is stated that up to the point of its cut off in the cylinder, the user has to pay for the energy thus created by the boilers. When the flow of vapour from the generators is stopped at any part of the stroke of the piston, the rest of the work is done for *nothing*, and with more or less liberality, according to the manner in which the engine is supplied with the motive power, which the accompanying table will show at a glance.

TABLE OF STEAM USED EXPANSIVELY.

Initial pressure in pounds per square inch.	AVERAGE PRESSURE IN POUNDS PER SQUARE INCH FOR WHOLE STROKE.					
	PORTIONS OF STROKE AT WHICH STEAM IS CUT OF.					
	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
100	96·6	91·9	84·6	74·4	59·6	38·5
110	106·2	101·1	93·1	81.8	65·6	42·3
120	115·9	110·3	101·5	89·3	71·5	46·2
130	125·6	119·4	110·0	96·7	77·5	50·0
140	135·2	128·6	118·5	104.1	83·4	53·9
150	144·9	137·8	126·9	111·6	89·4	57·7
160	154·6	147·0	135·4	119·0	95·4	61·6
180	173·9	165·4	152·3	133·9	107·3	69·3
200	193·2	183·8	169·2	148·8	119·2	77·0

After having explained how the expansion of steam in the engines affects the size of the boilers, let us now see how the increase of pressure improves their fuel economy. This is, to at least some extent, due to the small additional amount of fuel required to raise steam from a low to a high

pressure. That is to say, when water in a boiler is at 212° Fahr., the steam pressure is the same as the atmosphere: at 228°, it is 5·3 lbs. above the atmosphere; at 240°, 10.3 lbs.; at 302°, 55·3 lbs.; at 324°, 80·3 lbs.; at 353°, 125·3 lbs.; at 401°, 235 lbs. per square inch, and so on.

The description we have given of the Babcock & Wilcox boilers will sufficiently explain their merits from nearly every point of view. It may only be added that they have been made to carry steam up to from 300 to 400 lbs. pressure, and have been most extensively used for every possible purpose. They have also recently been successfully applied in a modified form to steamships, for which special designs have been prepared.

CHAPTER XXVI.

WATER TUBE BOILERS—*continued.*

Recent Types of Boilers—Their Evaporative Powers—Working Steam Pressures of 300 lbs.—Treatment of Tubes—Large power Boilers and their Treatment—Their Construction—Bursting Tests of Steel Tubes—Comparison of Weights of different kinds of Boilers—Value of good Circulation—Best method of studying its Action—Improved Management—Automatic Feed Appliances—Official Inspection and its Results—Construction and Uses of Evaporators—Advantages of Multiple Effect Apparatus—Cost of producing Fresh Water—Mechanical Shovel Stoking and its Advantages.

HAVING described in the last chapter the leading features of a type of water tube boiler which has now been long enough in existence and sufficiently employed throughout the globe to establish the general excellence of the system, we may turn to those of other firms who have recently introduced improvements of their own. Take, for example, those of Messrs. Hornsby and Sons, where, although the same broad principles exist which distinguish those previously noted, changes have been introduced in detail, with the object of ensuring the highest efficiency in other ways.

These, in the main, consist of a specially arranged steam and water drum, a series of specially headed inclined water tubes, and a water cased cylindrical furnace placed inside the front part of the combustion chamber, and extending underneath the tubes for nearly half their length. Everything that the most matured practice could suggest has been introduced into these boilers, the result being

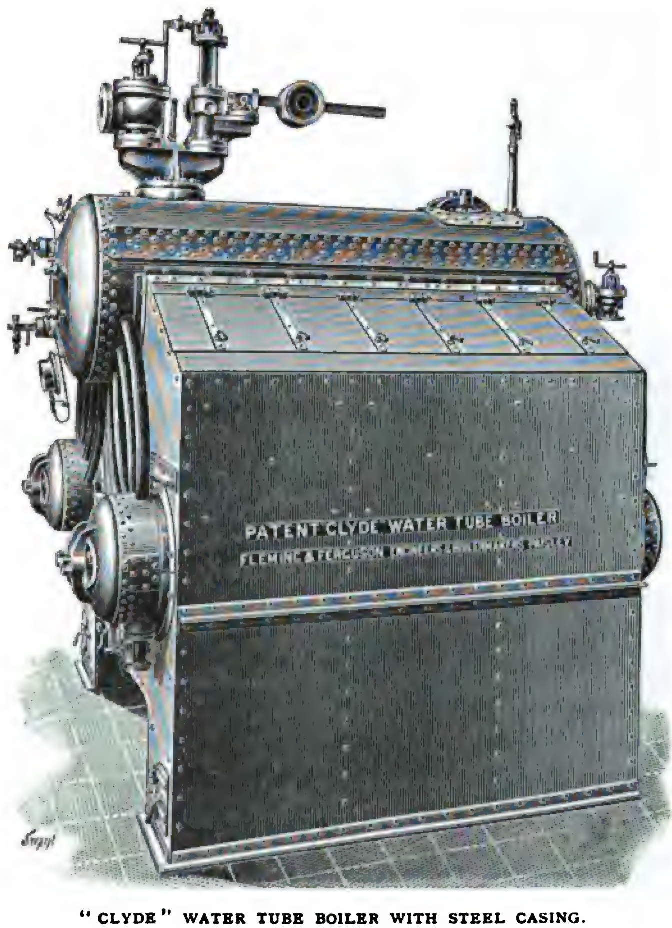
that, according to the reports of well-known experts, an experimental trial of from seven to nine days' duration produced an evaporative result of 9·2 to 10·98 pounds of water per pound of coal, according to its quality, the temperature of the feed water having been in each case 212° Fahr.

It is astonishing how much of the best marine practice in compound, triple, and quadruple expansion machinery has, during recent years, been utilised by the land engine fraternity, especially with regard to water tube boilers, of which the following is one of the most important examples. To explain the leading principles of design in these, would be to recapitulate much that has already been said on the subject, the real difference being in arrangement, which here is totally dissimilar to that of the preceding examples, as may be seen from the three following views of steam generators.

The first illustration represents a side view of one of these, complete with steel casing and mountings, and constructed for a working pressure of 300 pounds per square inch to Government rules.

The second view shows the same boiler with casing removed for the purpose of exhibiting the relative disposition of the tubes. This boiler was tested to a pressure of 650 pounds, and has been in constant use for over four years, supplying steam to a set of quadruple land engines. It has given no trouble whatever, and, while steam has repeatedly been raised from cold water, no signs of leakage have been observable. In practice, the feed supply passes through coils in the smoke box, and is heated to about 100° before entering the end of the upper drum. Since being put to work this individual boiler has been under the satisfactory inspection of the Board of Trade, Lloyds, and the British Corporation surveyors, and on the occasion of

an experimental trial with ordinary Scotch coal, it was found that when 4,400 pounds of water were evaporated per hour, the coal consumption was 480 pounds, the air

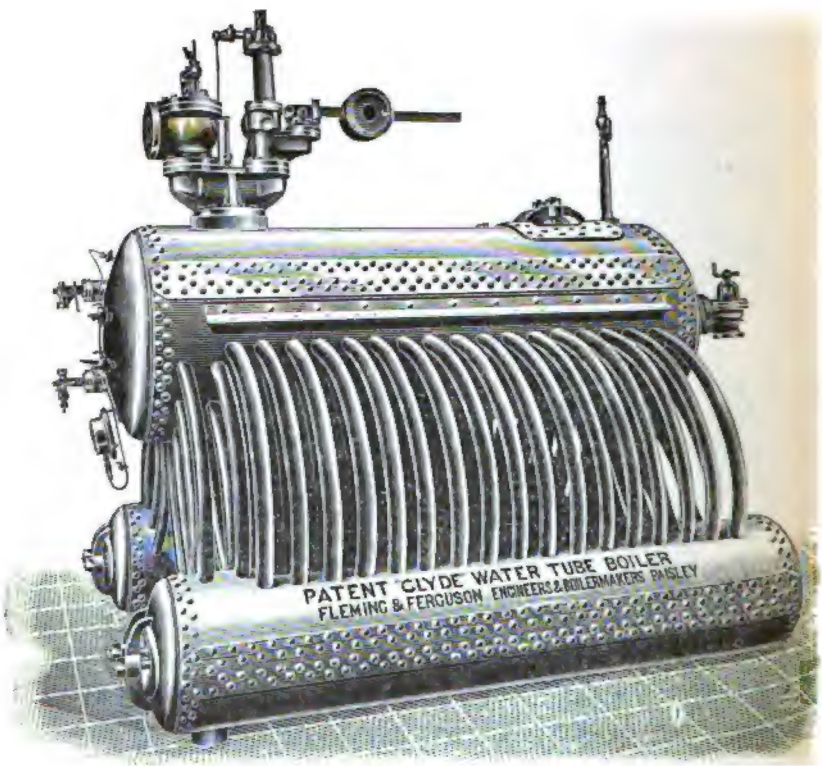


"CLYDE" WATER TUBE BOILER WITH STEEL CASING.

pressure in the ash-pit being ·3 inch, and the temperature in the chimney 480°. When the full firing trial was made, the boiler evaporated 5,500 pounds of water per hour, the

double plated and asbestos-packed casings around it being much cooler than an average smoke box.

We may here remark that in early days, when steam pressures were below 30 pounds, and copper pipes of thin material, their heat expansion was easily provided for,



"CLYDE" WATER TUBE BOILER WITH CASING REMOVED.

in straight lengths, by means of the "bellows" joint and elegant flat disc joint, *bent* pipes at all times providing sufficient natural flexibility. When, for high pressure purposes, these became too thick for safe springing, the two

former systems were discarded, stuffing boxes being used instead, or bends sufficient to relieve the otherwise destructive strains, and it is this last system which is now found so useful in the tubes of the boilers under review.

As will be seen, all the drums are internally accessible for cleaning or for examination by means of the manholes, with bridged doors which can be easily removed at any time.

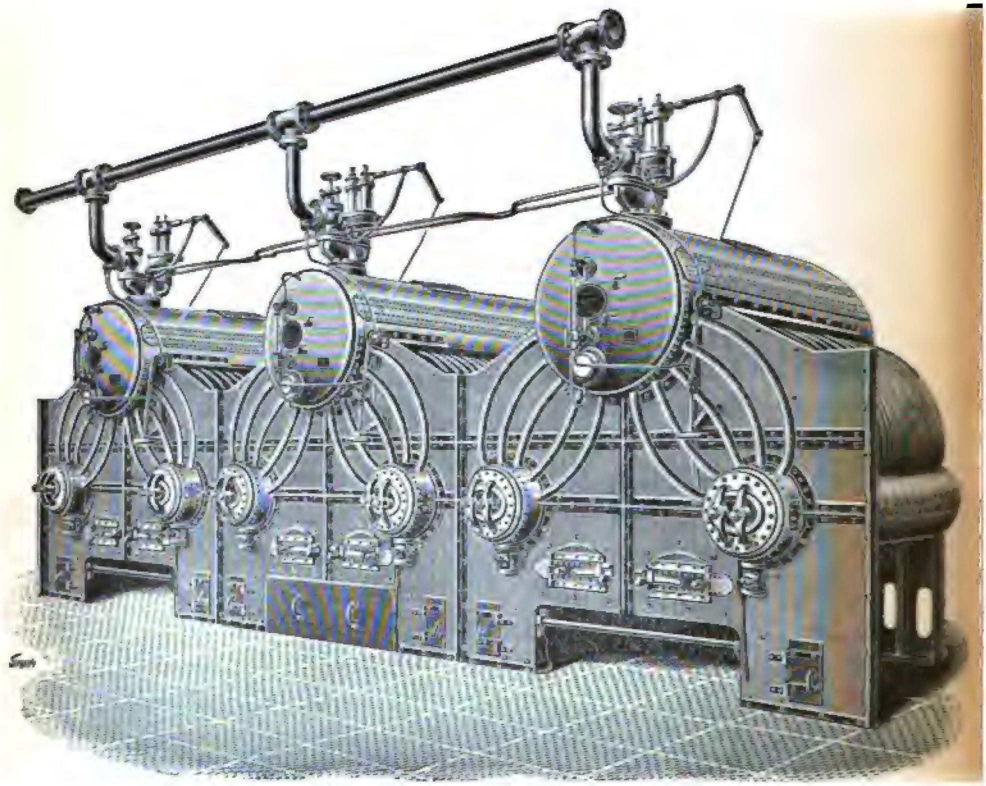
The last view illustrates a set of these boilers, also for land purposes, having a steel front plate only, the setting being in brick. So far as their evaporative efficiency is concerned, numerous tests have shown that in general, this amounts to 10 pounds of water per pound of coal, with natural draught, while the economy in coal effected, as compared with those of the locomotive type, is 10 per cent.

Steam producers of this type are specially suitable for high powers, as they so greatly obviate the necessity for subdivision into a number of boilers, with their numerous fittings and mountings. The usual diameter of the tubes is one which enables them to be readily cleaned. The drums, too, are of ample size, thus allowing a good supply of water to be always in the boiler, as well as sufficient steam space, by which means liability to prime is removed, and, at the same time, the regularity of the water level is reduced to a practical certainty.

One of the special features of the water tubes is the ease with which any one of them can be taken out and replaced without disturbing the others, their short length and curved shape, together with large diameter of the steam drum, making it possible for any tube to be drawn into it, and replaced in the same way.

Other points worth noticing are, that all rivets and joints are kept clear of the fire, and the heating surface is

very large in proportion to the size of the boiler. The tubes are also not so crowded together as to prevent them from being readily accessible for cleaning, even when the boiler is under steam, by means of a rubber tube and



INSTALLATION OF THREE "CLYDE" WATER TUBE BOILERS.

steam jet. Then, again, the boiler is well adapted for working with forced draught, either on the fan or on the steam jet principle, and the furnaces can be specially constructed to suit any kind of fuel.

For land installations these boilers may be set in brick work, or supplied complete with furnace fronts and sides of steel plating, as in the marine patterns. They can also be forwarded to their destination completely fitted together ready to be placed on their seatings, or the drums and tubes can be prepared, marked, and packed separately. When in this latter form they can be readily shipped, or transported over bad roads, each section being very light and all of them capable of easy erection by ordinary workmen.

From a constructional point of view this boiler is everything that can be desired, as there are no *flat* surfaces, with their closely pitched stay bolts and unavoidable evils, to take into account. Indeed, no stays at all are required, as the steam and water chambers are cylindrical.

Then again, the tubes are of steel, and of enormous strength, as may be gathered from the fact that out of a number of them of the Credenda cold drawn seamless manufacture experimented upon by Sir Joseph Whitworth & Co., it was found that while a tube 1″ bore and $\frac{1}{16}$″ thick burst with a pressure of 4·4 tons per square inch, another tube $1\frac{7}{16}$″ bore and $\frac{1}{8}$″ in thickness only required 5·3 tons to rupture it. As the strength of tubes of equal thickness to resist transverse tension is inversely proportional to their diameters—their similar strength when of the *same* diameter varying progressively with their thickness—it is easy to find the approximate bursting pressure of tubes or pipes of any dimension so long as the quality of the material is known, allowance of course being made for welded and riveted joints.

The tubes in the boilers under review have their ends expanded into the drums, whilst the latter are of comparatively thin plates and correspondingly light riveting,

all of which in combination have simplified the process of manufacture, and helped to reduce the weight to the utmost, not so much in land boilers, where it is frequently unnecessary, as in those for naval vessels, as shown by recent torpedo boat performances. This is confirmed by the fact that, according to Mr. Seaton, double ended cylindrical boilers, made in accordance with Board of Trade Rules for a working pressure of 200 lbs. per square inch, weigh 196 lbs. per I. H. P.

On the other hand, the "Babcock-Wilcox" weighs 115 lbs. per I. H. P. with the same pressure, and similarly the "Thornycroft" and "Yarrow," working under forced draught, have a weight of only 20 to 21 lbs. per I. H. P., whilst those of the locomotive type weigh 33 lbs. per I. H. P. It may here be added that, although all these water tube boilers can easily carry working steam of at least 300 lbs. per square inch, this pressure may be reduced to, say, 200 lbs. or so, to suit the engines.

There is a further reason than that of the merely constructive nature already referred to for the wonderful lightness of these boilers. Mr. Thornycroft has himself declared that circulation in boilers is simply the "passage of the water from the surface of the steam generator to its lower portion, and thence returning again to the surface by a complete *circular* motion, which is quite distinct from the mere movement of the fluid from the point of admission to the point at which it becomes steam."

Where this circulation can be made systematic throughout, and where the heating surface is much larger than usual, steam can be more rapidly generated, hence the quantity of water may be greatly reduced, thus requiring less steam space. This latter, in ordinary cases, has a ratio of about 90 times the content of the high

pressure cylinder to be supplied, the ordinary "Thornycroft" boilers, however, have a ratio of 30 to 40 times only. With reduced water and steam spaces less material is required. Moreover, in the water tube boiler, all the metal employed holds either steam or water, and is therefore a necessary part of its construction; whereas, in the old form of cylindrical boiler, the vessel which contains the water and steam has also to hold a pressure resisting space for containing the furnace and products of combustion. The result of this is that the space for combustion so obtained is necessarily cramped, whilst in the water tube boiler, where it is no longer necessary to inclose a fire in a chamber which is under pressure, much more room can be allowed for the fire-box, and therefore a much better chance is given to the gases to combine before escaping to the chimney.

However simply explained the process of circulation may be, it is impossible to comprehend it properly without the aid of specially prepared models which enable people to see clearly the action of heat upon the fluid contained in them, and which are powerful object lessons of great usefulness. By this means, the method of thoroughly disseminating the heat throughout the water of a boiler, thus avoiding injuriously unequal expansion of the metal and the deposit of sediment, may be fully understood.

Perhaps no branch of mechanical engineering science has of late years caused so much discussion, owing to the difficulties by which it was beset, as that under consideration. Briefly put, those difficulties were created, as in many other cases, by the very imperfect manner in which a magnificent principle was so treated in detail as to cause failures enough to greatly retard the extended application of the system. Now, however, much that was

faulty has been eliminated, and therefore the boiler of to-day will probably be that of the future, with but few alterations.

As evidence of this, one has only to note the immense numbers continually being made in America and in England. This is owing to the fact that whilst formerly it was difficult to obtain water for them which was free enough of scale-producing substances, the introduction of *Evaporators* by means of which pure water could easily be obtained in sufficient quantity, together with a more complete knowledge of the laws of perfect circulation, enabled progress to be made by leaps and bounds to the present. This was accentuated by the unsuitability for tubes of non-corrosive metals, such as brass and copper, the former being unable to stand high temperatures, and the latter rapidly deteriorating from the same cause.

Another circumstance which greatly helped these boilers to success was improved management, which became absolutely necessary owing to their great sensitiveness as rapid steam producers containing only a small quantity of water at a time, and therefore occasionally liable to have within them either too much or too little.

To avoid these dangers, an *Automatic Feed Arrangement* was introduced which, in various forms, has proved most acceptable. That adopted by Mr. Thornycroft consists of a valve and float so placed inside the steam and water drum, upon the improved ball and cock system, that the float, in rising and falling with the water level, either shuts or opens the valve by means of a lever, and thus regulates the supply. To prevent the possibility of derangement of this gear, some of its parts are specially fitted with well designed safety contrivances, that perform what is needed. Other firms employ methods of their own

which, in different ways, tend to perfection in working, but to these we need not refer.

It may be useful here to note that with proper care the water tubes, which formerly gave so much trouble, now do not give any, the result being that while, on the one hand, locomotive boiler tubes in the navy last about four years, those in Mr. Thornycroft's boilers have lasted, under similar conditions, for an average period of about eight years. Indeed, so far as we can learn, they endure for a longer period under hard service and careful management, whereas their deterioration through corrosion is practically greatest when idle, as one might naturally expect.

There is a point of great importance in connection with boilers of every description to which no reference has yet been made, and that is their systematic and official inspection. Before this was organised, serious disasters were very frequent, partly from bad design, but chiefly from overwork on the part of employers, and also from the carelessness of attendants. These are now so much things of the past that it is hardly possible for any boiler to explode disastrously; firstly, because extreme precautions are taken in every respect by the builders to ensure strength and good wearing qualities; secondly, owing to the most careful management; and, lastly, to a supervision by the Insurance and other companies which roots out every fault before it becomes dangerous.

So well watched over are our boilers from beginning to end that, during the last eleven years, only one insured boiler in 11,000 in the United Kingdom exploded annually, and only one death occurred in the same period for every 14,000 boilers. It must be remembered, however, that many secret causes of a chemical and heat-expansive nature brought on rapidly destructive internal corrosion, etc.,

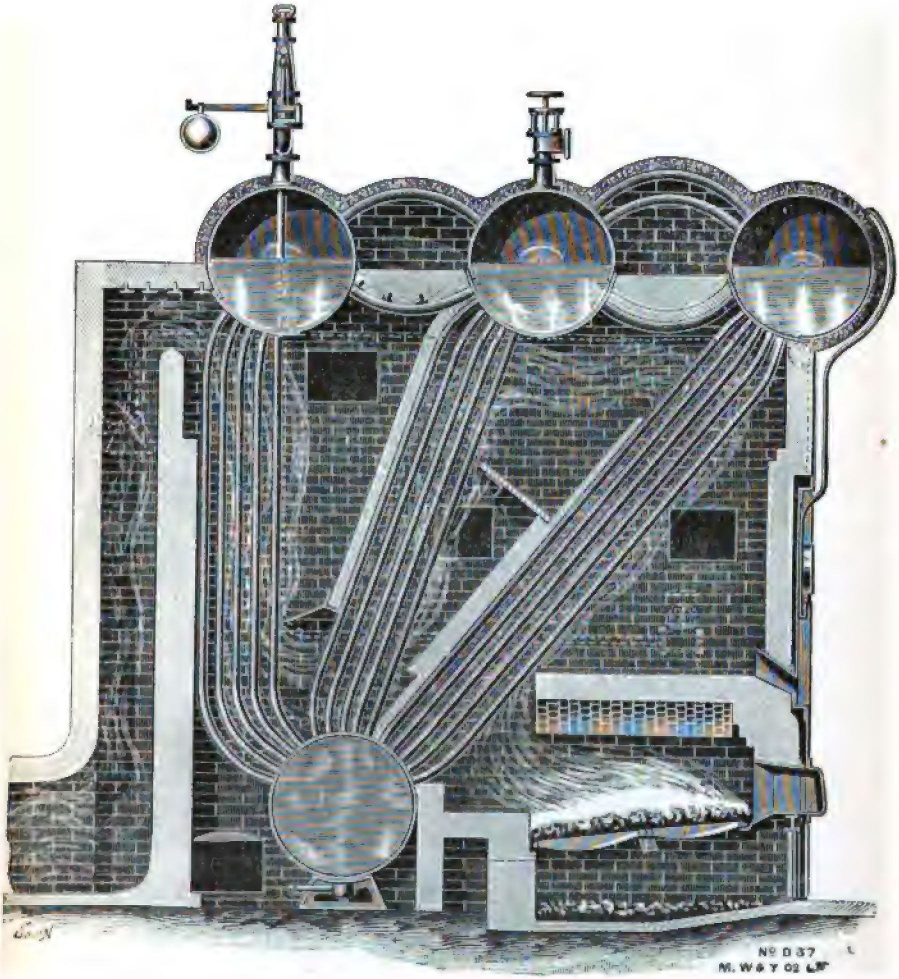
which in these days have been so much eliminated that the boilers of the present are about as safe as it is possible to make them. In spite of all that can be done, however, they will explode at rare intervals, and as this, with high pressure cylindrical boilers, may mean the sinking of a ship, or the destruction of a costly building, and loss of many lives, the water tube boiler is extensively used instead, partly for its greater safety, and partly for economy, and also from the fact that its construction is so simple that every part can easily be kept in the most perfect order under every possible circumstance, as may be gathered from the illustrations in this and the previous chapter.

The last example we shall give is one of the latest and most practically successful boilers, which is now being made by the Mirrlees, Watson and Yaryan Co. Limited, of Glasgow, and which may be fully understood from the three following engravings, the first of them being a very expressive longitudinal section showing the whole process of steam raising, with brickwork, mountings, non-conducting boiler coverings, etc., complete.

The advantages of the Water Tube Boiler system as a whole have already been referred to, the steam generator, however, now under review, requires a little explanation on account of its peculiar arrangement. This consists essentially of three upper steam and water drums, connected by tubes to one lower drum, which latter serves also as a mud receptacle, where solids, originally suspended in the feed water or thrown out by the evaporation, may be deposited. The upper drums are also connected together by tubes in their water and in their steam spaces.

The course of the fire gases is clearly shown in the sectional view, from which it will be seen that they first

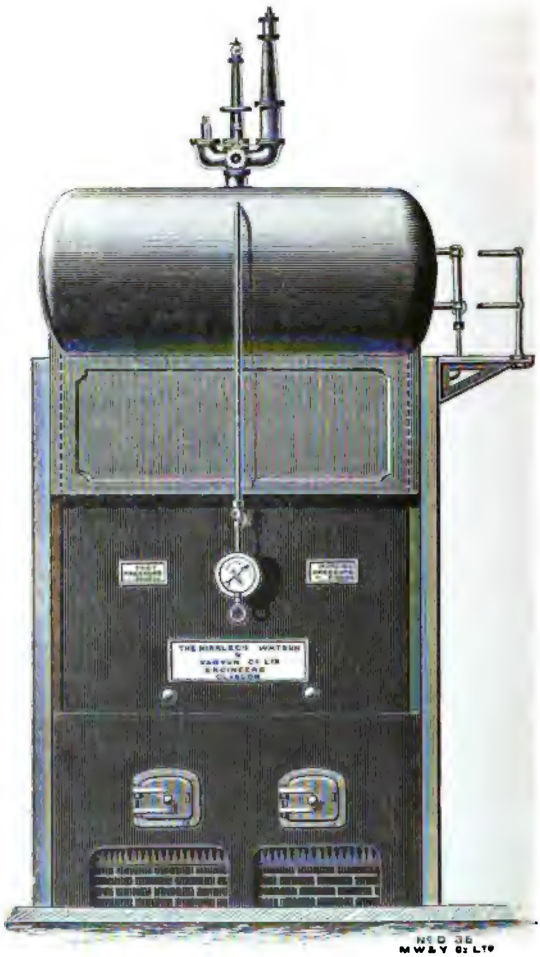
impinge directly upon the lower portion of the first section of the water tubes, and are then compelled by the fire tile



WATER TUBE BOILER—LONGITUDINAL SECTION.

partitions to travel along and across the remaining lengths of tubes, thus enabling the heat of the furnace to be most

efficiently absorbed by the water, and most fully productive of good circulation.



WATER TUBE BOILER—FRONT VIEW.

Access to the interior of the tubes for examination or cleaning is obtained through manhole doors in the ends of

the four drums, and to their outside by means of door frames built into the side walls. The feed water is admitted by the valve and pipe, shown in dotted lines, to the back steam and water drum, from which it descends to the lower drum before entering into the circulation of the principal steam generating portions of the boiler. The engraving on the opposite page gives an external front view of the same boiler.

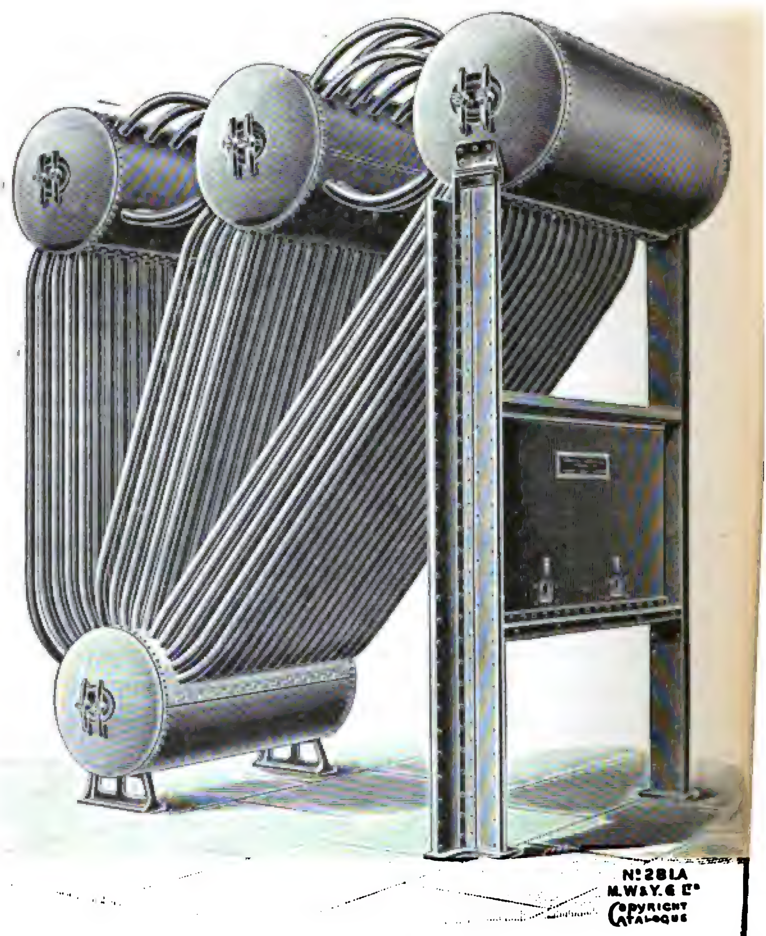
The following engraving illustrates one of these erected ready for enclosure by the walls, and for receiving the furnace and other attachments. It also shows its complete independence of the brickwork, and the ease with which all its parts are made capable of ready transport over hilly or otherwise difficult territory.

This boiler is made in numerous sizes from 8 to 150 British nominal horse power, and from 11′ 6″ in length by 4′ 0″ in width, to 24′ 0″ by 12′ 6″. Its approximate total weight, with standards, as shown in the last view, ranges from 24 to 275 cwts., the weight of the heaviest drum being from 364 to 3,500 lbs.; this, however, if too heavy for transport, can be made in sections capable of bolting or riveting together. Here the term "horse power" is equivalent to an equal number of cubic feet of 62·5 lbs., or 28·4 kilos of water evaporated per hour. This, however, must be distinguished from "American" or "Centennial" horse power, which equals an evaporation of only 30 lbs. of water.

Lastly, these boilers, though usually constructed for a working pressure of 133 lbs. per square inch, can be made for much higher pressures if required.

Perhaps nothing in later years has appeared so ridiculously unpractical as that of feeding boilers with impure water, and *then* applying internal remedies to correct the

very serious evils thus most unnecessarily engendered, such as corrosion, pitting, scaling, and possible burning and collapse of furnace crown plates, frequently involving



WATER TUBE BOILER AND SUPPORTS WITHOUT BRICKWORK.

premature destruction of the boiler. The only excuse for such vicious treatment is to be found in the fact that,

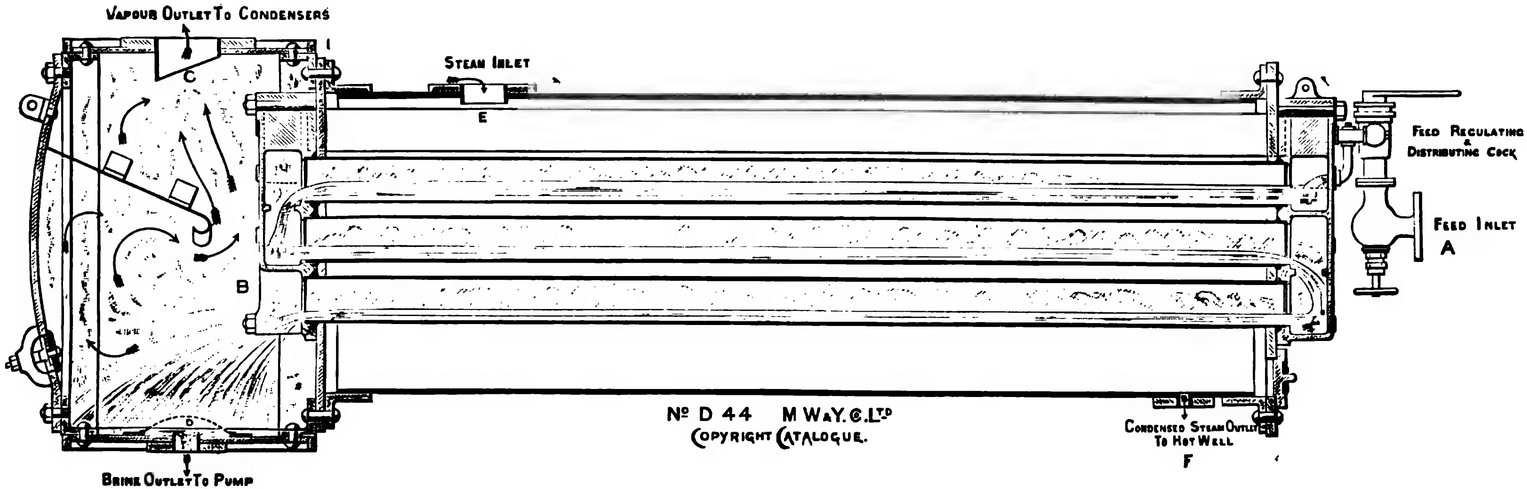
until recent times, no method of conveniently or economically producing pure water could be had.

The view on next page is a section of one of the Mirrlees, Watson & Yaryan Company's *Marine Evaporators*, which, in extended form, is largely employed for land purposes, and which clearly indicates the method of producing fresh water for drinking, boiler feeding, and numerous manufacturing purposes.

As shown in the engraving, the apparatus consists of a cylindrical shell of steel or copper, the heating tubes being of brass solid drawn. The tube plates are of steel or gun metal, into which the tubes are expanded, or secured by a simple rubber packing, which makes a perfectly tight joint, and permits their easy removal when necessary.

The principle of this apparatus consists practically in the boiling of a liquid whilst traversing a series of straight tubes upon the coil system, the liquid being so regulated that it only partially fills them, thus leaving space for the liberation of vapour and its free escape. Under these circumstances, steam is very quickly generated, whilst the rapid and continuous movements of the liquid through the tubes helps to keep the latter clean; the greater proportion of any solids held in suspension or thrown out by concentration being carried into the separator, from which they are removed by means of a pump or otherwise. The boiling of the fluid may take place either under vacuum or under pressure, and the apparatus may be constructed either in single or in multiple effect as required.

The evaporator is provided with all necessary mountings, including safety valve, reducing valve, pressure gauges, both for the steam shell and for the separator, and also glass gauges to show the level of water in the former, and of brine in the latter.



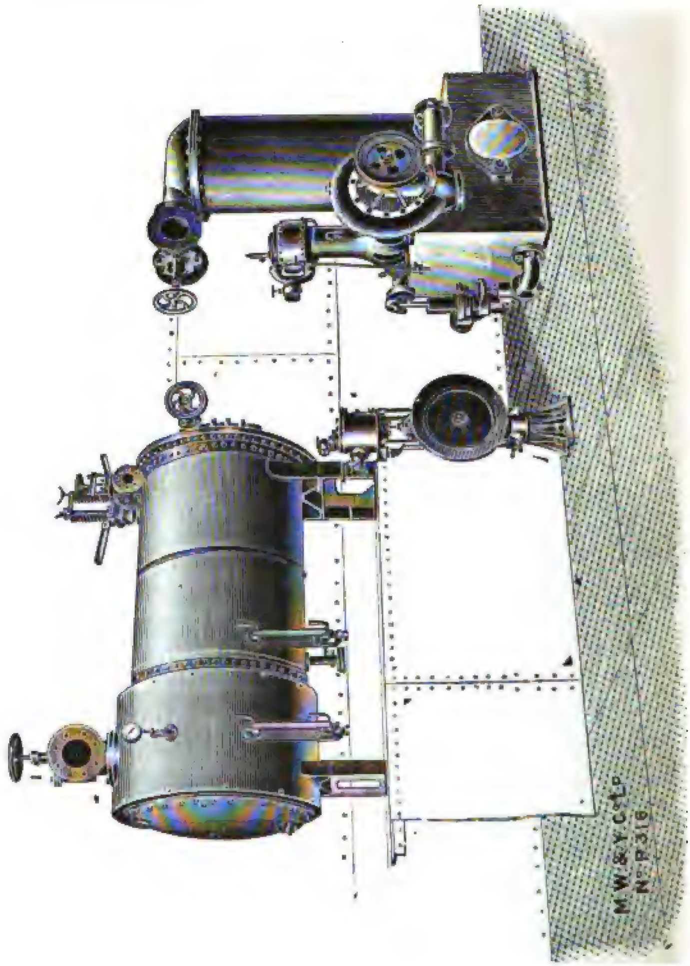
"YARYAN" MARINE EVAPORATOR—LONGITUDINAL SECTION.

The illustration on page 484 represents externally a Marine Evaporator for supplying 35 tons of water per day, suitable for drinking and other purposes, with distilling condenser, pumps, and fittings complete, as supplied to several Governments.

The fresh water condenser is vertical, and placed upon a substantial base constituting a small receiver for containing the drinking water produced by the condensation of the steam after passing from the vapour outlet valve to the condenser. The circulating pump is of the centrifugal type, driven direct by a small engine, which also works a pump for withdrawing the pure water and delivering it to the store tanks. The receiver is provided with an air-cock, by means of which the water is at once aerated and cooled, whilst an independent vertical pump is employed for the purpose of withdrawing the concentrated brine from the evaporator and discharging it overboard. For land purposes the same arrangement can be used; but as the object on shore will naturally be to produce a maximum of water for a minimum of fuel, and there will be no very narrow limitations as to space occupied or weight of plant, multiple effect, instead of single effect, apparatus will usually be adopted.

The value of the *Multiple Effect* system may be gathered from the fact that by its employment we can obtain pure distilled water in quantity, and at a price which brings it within practical limits for the use of whole towns and districts that are devoid of a natural supply. For example, with a Single Effect apparatus every 100 lbs. of primary steam raised in the boiler produces an additional 75 lbs. of fresh drinking water. A Double Effect, on the other hand, produces 150 lbs. for the same quantity of steam, and so on, until, by the employment of Six Effects, the apparatus

will yield 450 lbs. of pure distilled fluid, the primary steam being in all cases returned to the boiler to avoid feeding with salt water.



"YARYAN" MARINE EVAPORATOR WITH ACCESSORIES.

Otherwise expressed :—Assuming that 8 lbs. of water are evaporated in the boiler per pound of coal, this quantity of fuel would produce 6 lbs. of fresh water by the Single

Effect, and 36 lbs. by the Six-Effect process, which clearly shows the advantage gained by the latter when the first cost of the apparatus is not a leading consideration.

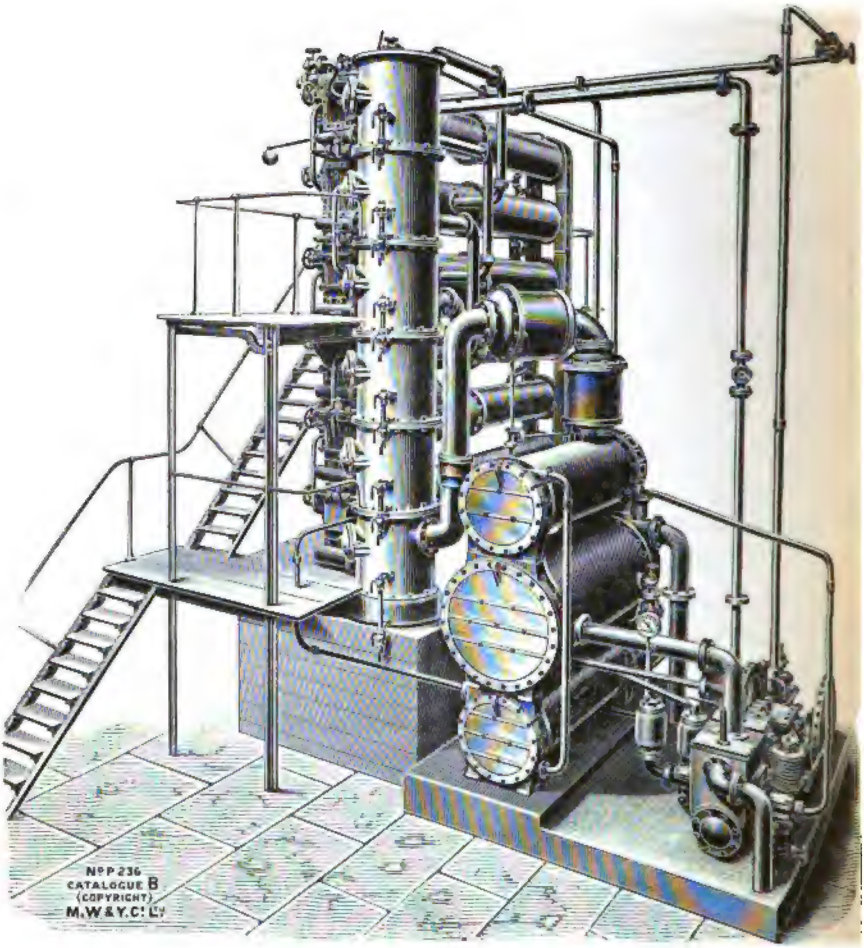
As the employment of pure water in all boilers is most important, it may be interesting to show on next page a Six-Effect Installation erected by the firm already named, at Perim, Red Sea, for producing 40 tons of water per 24 hours; and also, in the end of 1896, at Mombasa, for the purpose of supplying feed water to the locomotives of the new Uganda railway, as well as for drinking purposes. To describe this arrangement in detail would be unnecessary after what has already been said, but those who wish further particulars may consult *Engineering* of May 22, 1896.

The actual *Cost of Production* will vary, of course, with the price of fuel, and other details dependent upon the locality and situation of the distilling plant, but, within certain limits, a fair allowance for the above apparatus is from one to two shillings per ton of 224 gallons, which shows a large margin of profit on the price charged for fresh water in many foreign ports.

The last notes we shall make in reference to boilers are connected with the economy of fuel-feeding in the furnaces, as exemplified in Messrs. Proctor's mechanical system of *Shovel Stoking*, which is adopted very successfully on an extensive scale, the Crewe establishment alone, which began with four of them on trial, having now forty in use; an external view of one of them is shown adjacently.

The mechanism of the appliance, as shown in outside view on page 487, consists of a hopper for supplying coal to either one or two furnaces; a shovel or tray, which partly enters the furnace, and upon which the coal is deposited; and gearing of a simple character driven by a

cord cone pulley, which regulates to a nicety the supply of fuel to a boiler. The action of this stoker is to place the

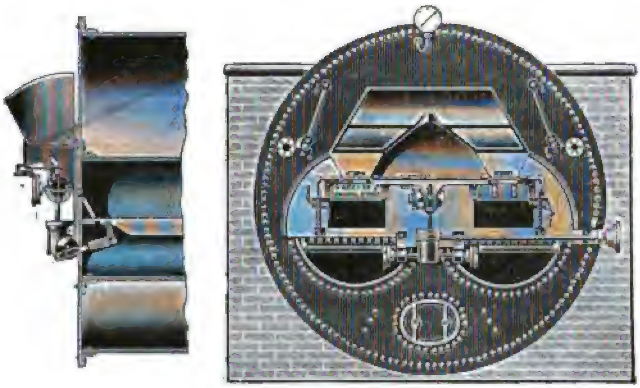


"SIX-EFFECT" FRESH WATER DISTILLING APPARATUS.

coal evenly and regularly upon the fire, and only in such quantities as to ensure proper combustion in the furnace,

and this, too, with an expenditure of so little power that a $\frac{5}{8}$" diameter rope will drive the machines for even three furnaces, when in complete working order.

The advantages of this Mechanical Stoker consist of an avoidance of the smoke nuisance, and also a more constant pressure of steam, hence a more regular speed of engine.



MECHANICAL SHOVEL STOKER.

It dispenses with the frequent opening of the fire door, thereby preventing large volumes of cold air from impinging upon the hot plates. The horse power of the boiler is raised fully 20 per cent, and a saving of fuel of from $7\frac{1}{2}$ to 15 per cent. is effected, as indicated by the reports of many users, not to mention other advantages of a subsidiary nature which are so apparent as not to require description.

CHAPTER XXVII.

GAS AND OIL ENGINES.—LIVERPOOL OVERHEAD ELECTRIC RAILWAY.

The Gas Engine—Its Advantages—Gas Producing Plant—Its Economy—Petroleum Engine—Practical Applications—Liverpool Overhead Electric Railway—Its Primary Difficulties—Novel Features of the Line—General Arrangement of Superstructure—Foundations—Columns, Girders, and Roadways—The Permanent Way and its Electrical System—Considerations affecting Design of Rolling Stock and Motors—Generating Station and its Arrangements—Main Driving Engines—The Dynamos and their Connections—Peculiar Tractive Features of the Railway—Relative Economy of Steam and Electrical Power—Great Success of the Line—Electrical Accumulator and its Applications.

HAVING previously described various kinds of dynamo driving engines, and also the boilers that supply many of them with steam, we may add a few remarks upon two classes of motors which now perform splendid work without the aid of any boiler whatever. These are of the *Gas* and *Oil* classes, both of which have attained a very high reputation, and are therefore most extensively used for many purposes.

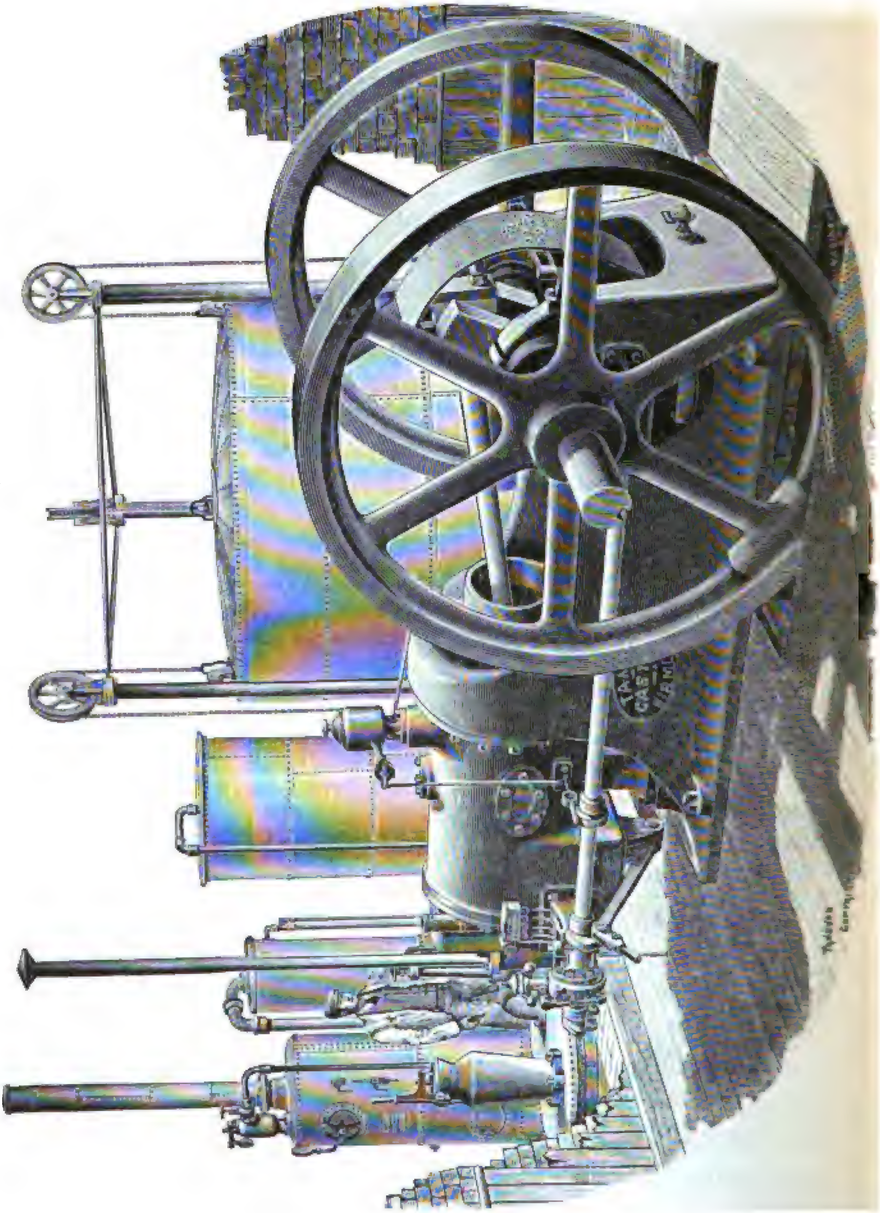
The *Gas Engine* utilises heat force in a manner quite different from that of the steam engine—combustion, explosion, and expansion being advantageously combined in a peculiar way. With the latter there is an unavoidable waste of fuel in raising steam, and also during intervals when the engine is idle, or when intermittently employed. With the former, however, nothing of this kind exists, as the engine begins to work at once when the gas is lit, and

stops when it is extinguished. A gas engine is not merely a single acting motor, owing to the pressure on its piston being only at one end, but a percussive one at the same time, as each supply of gas and air is exploded with great force. In the early engines this caused much noise and harsh action, but so greatly have these been improved by Messrs. Crossley Brothers, and others, that the motion of the present machinery is now perfect, owing to the better design of its details, and the application of either one or two heavy fly-wheels that store up the intermittent energy and thus produce very smooth and steady working.

Gas engines do not require such careful attention as those having steam boilers, as there is neither fire to feed nor water level to maintain, nor, indeed, any of the critical supervision so constantly needed by the latter. Hence the former have been found very useful in private houses, printing establishments, warehouses, workshops, and for a great variety of other purposes, including dynamo driving, etc. In city workshops, or in crowded buildings generally, a gas engine has the special advantage of freedom from the risk of fire, consequently the cost of insurance is not so great as in other cases.

Besides these qualifications, its cleanliness, simplicity, ease in manipulation, and great compactness of arrangement are strong recommendations, not to mention the facility with which it can be used as an auxiliary to large steam engines, either for supplying the boilers with water, or driving one or more machines, or for performing other useful work when only a small amount of power is required, or where the service is too small, or too intermittent for the economical employment of a steam engine.

The adjacent plate illustrates one of the above of 40 nominal, 115 indicated, and 98 brake horse-power, by



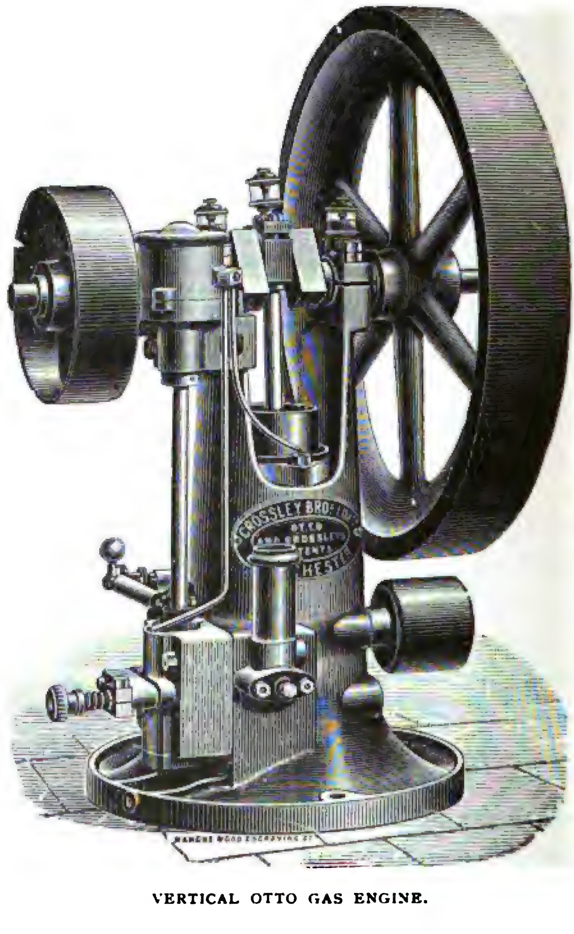
Messrs. Tangye. As these are confusing terms to many, we may here observe that the first named is a commercial phrase still used for the smaller class of engines, but as no fixed standard of value is now attached to it, the *Brake* horse-power should alone be considered, as it is the power actually given out by the fly-wheel shaft.

Indicated horse-power, on the other hand, is the energy produced in the cylinder alone, which becomes reduced to the last named after the friction of all the working parts has been allowed for.

The working principle of the above engine is that so universally known as the "Otto," modernised by the introduction of recent improvements which have had the effect of simplifying and reducing the number of working parts, and of rendering the engine less liable to disarrangement when worked by unskilled people. With sufficiently heavy fly-wheel power it will drive a dynamo with great steadiness by means of a belt from the wheel instead of a pulley, so that the proper speed may be obtained.

Before being sent from the Works, these engines are carefully tested under the dynamic brake to ascertain experimentally their real power. They are also run for a sufficient period to ensure the perfect adjustment of all parts, and the discovery of the exact quantity of gas used in working. By this process it has been shown that the consumption of gas of 16·5 candle power is found to average from 16 cubic feet per indicated horse-power per hour in the larger, to 25 feet in the smaller sizes, or 19½ to 29 cubic feet respectively per *brake* horse-power per hour. At 25 feet per I. H. P. as above, with gas at say 3s. 4d. per 1000 feet, the cost of gas consumed would be one penny per horse-power per hour; and so on, more or less, according to circumstances.

An extremely compact and useful vertical engine is shown in the following view. It has been designed to meet the demand for a small engine for the convenient



VERTICAL OTTO GAS ENGINE.

employment of many who want power. This will work up to $\frac{3}{4}$ H. P., the consumption of gas being in proportion to the power required, and if, say, only one man power

is needed, the governor will cut off the gas to suit. As will be noted, a belt may be placed either on the fly-wheel rim or on the pulley, and, if required, a pump may be combined with the engine and driven direct.

If these engines could only be used where a town's supply was available, their employment would be much restricted, especially if the gas is costly, as it sometimes is. To get over this difficulty, *Gas Producing Plant*, as shown in the plate on page 490, has been designed in view of the increasing demand for engines of large power which, though they cannot be worked economically from the town supply, can, with a suitable gas producer, be worked more cheaply than the best steam engine, the plant has also been designed for manufacturing gas suitable for heating purposes, and possesses many special features and advantages.

As an indication of its economy, it may be added that the consumption of fuel, equal to Welsh anthracite coal, at full load, is from ¾ lb. per I. H. P. per hour in the larger sizes of engines, to 1¼ lbs. in the smaller sizes. When compared with the steam engine its economy is still more intelligible, as we gather from the comparatively recent statement made by Sir Frederick Bramwell, on which occasion he said :—

"In an investigation instituted last year by the Corporation of Birmingham, when considering whether they should approve of a proposal to lay down power-distributing mains throughout their streets, it was found on indicating six non-condensing steam engines, taken indiscriminately from amongst users of power, and ranging from 5 to 30 nominal H. P., that the consumption in one instance was as high as 27·5 lbs., while it never fell below 9·6 lbs., and the average of the whole was as much as

18 lbs. In other words the fuel consumption in practical work was about 3 to 8 lbs. per I. H. P. per hour in those engines up to 200 horse-power."

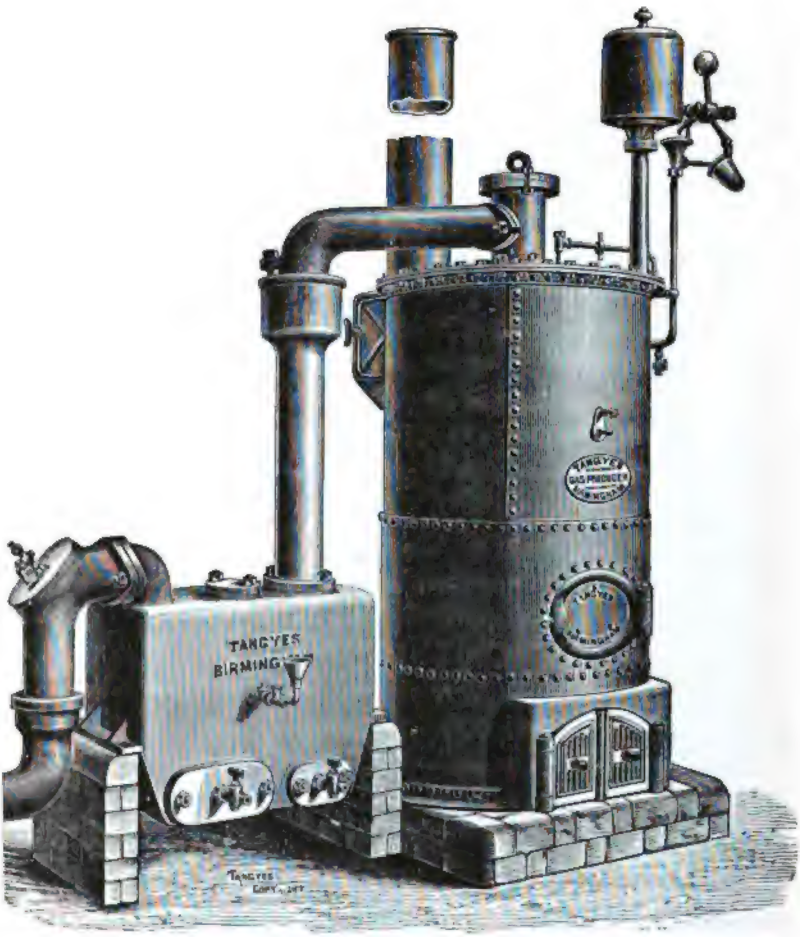
The engraving opposite of a *Hydro-Carbon or Oil Gas Producer* will give a good idea of another arrangement which has been designed to meet the demand for a cheap and reliable apparatus to be used in places where the ordinary town's gas cannot be procured, or is too expensive. It is specially suitable for lighting and heating purposes, and for working gas engines, thus enabling motive power to be applied for driving dynamos for electric lighting, and for pumping and other machinery as required.

The apparatus is very simple in construction, and its management requires very little trouble, the waste fats and dripping common to domestic and farm use being turned to account, either separately or mixed with cheap oils, for the purpose of gas making. After the fire has been lighted, vegetable refuse and cinders can be used in the furnace. The view illustrates an apparatus capable of supplying about 50 cubic feet of 60 candle-power gas per hour through an adjacent holder, the other sizes being of 100, 200, etc., cubic feet capacity, or sufficient to drive gas engines of 5, 10, 20, etc., brake horse-power.

Our previous remarks refer to a class of engine which has for its motive power either town-made or producer-gas. Now, however, we have to describe the *Petroleum or Oil Engine*, which is entirely independent of both of these, and, although only a recent innovation, it has rapidly become very popular.

This engine has been ingeniously adapted to meet the demand for a simple, easily managed motor, inexpensive in its consumption of fuel, thoroughly trustworthy, and at

all times immediately available for work. A motor, too, which can be applied to electric lighting, pumping, farm



HYDRO-CARBON OR OIL GAS PRODUCER.

work, and for giving motion to yachts, launches, traction and other engines, and also to multitudes of machines now

employed in every industry. Where steam is not readily available, and where solid fuel and water are costly and difficult to obtain, this engine is invaluable, one of the most useful types by Messrs. Tangye & Co., of Birmingham, being that shown on opposite page, which has been successfully employed for various purposes, whilst possessing at the same time, the leading features of the best gas engines.

The cost of working in the various sizes may be taken at about one half-penny per brake horse-power per hour, the incidental advantages to which reference has already been made in connection with the gas engine being here equally strongly marked.

This engine is identical with the gas engine by the same firm up to the combustion chamber. Here, however, a change occurs to suit the application of another motive power, which, when vaporised, acts explosively as in the case of gas. It is, perhaps, one of the most extraordinarily simple of the present day, as it makes its own supply of gas for instant use without any accessories whatever, the oil cistern alone on the top of the cylinder acting in the same way, and for the same purpose, as the previously mentioned producing plant, or the town's gas holder.

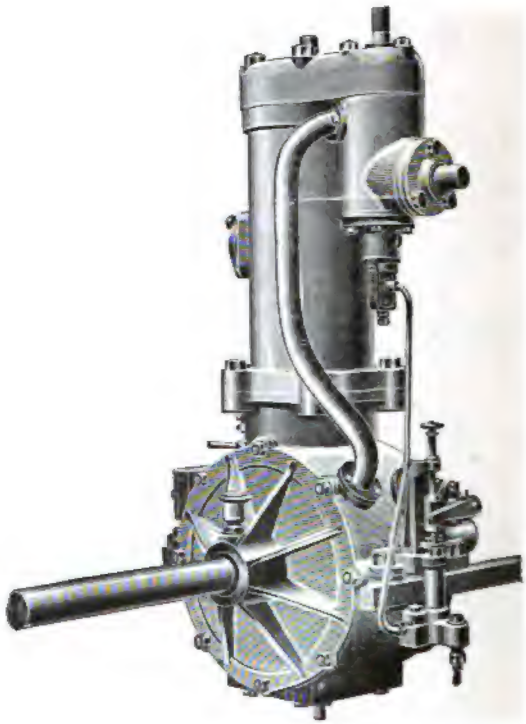
Another of the most useful of the recently improved oil engines, both for land and marine purposes, is that of the "*Facile*" description shown on page 498, which is remarkable for compactness and for extreme simplicity. It is easy to start, and to maintain in good working order, either as illustrated, or in horizontal form. It has also striking peculiarities of construction, chiefly of an internal nature, which have produced the best results.

Having described the methods of producing electricity, and also some of the driving engines employed for that

PETROLEUM OR OIL ENGINE.

purpose, let us now give a very interesting example of its application to railway uses.

The first successful *Electric Railway* in England was the "Liverpool Overhead," the demand for which was created by the unavoidably limited and imperfect services



"FACILE" VERTICAL OIL ENGINE.

of the dock omnibuses at a point of the city where the traffic is very heavy. So serious did these defects become that, in 1882, the Mersey Docks and Harbour Board originated a scheme for the construction of an overhead line 6½ miles in length. Before, however, anything could be done, a great many intricate problems had to be

solved, and numerous difficulties surmounted, owing to the peculiar circumstances of the case.

The New York system, having a total length of 35 miles, was carefully examined, and, although it had proved most advantageous to the public, having carried in a recent year at least 21,000,000 people, it was discovered that the employment of steam locomotives was very objectionable, and that as the elevated track had no floor, cinders, oil, water, etc., fell on the street, and on one occasion an engine actually slipped through. With these facts at hand, an improved method of construction in Liverpool was thought necessary. Much, however, had to be accomplished before the plans could be approved, but eventually the electrical system of traction was selected.

This line presents many features of novelty and interest chiefly on account of the method of working adopted, electricity being used as the motive power for driving the trains, controlling the signals, and lighting the stations, all of which are supplied from one generating station.

The railway itself consists of an iron structure carrying a double line of rails of the ordinary 4′ 8½″ gauge, running for a distance of six miles along the docks, for a greater part of its length over the existing Dock Railway, and giving a clear headroom under the girders of 16 feet. Near the Bramley-Moore dock the line is carried by an embankment, for a distance of 270 yards, running underneath the Lancashire and Yorkshire High Level Coal Railway. At this point there is a dip, having a gradient of 1 in 40 on each side, so that the trains will clear the lower part of the bridge which crosses them, the remaining part of the line having easy gradients, and the sharpest curve a radius of six chains.

The *Foundations* of the structure chiefly consist of blocks

of concrete, the supporting columns for the girders being of the riveted channel bar and plate box section referred to on page 408. The ordinary distance apart of these was fixed at 50 feet; but where obstructions existed, the spans were either reduced to 30 feet as a minimum, or increased to 98 feet as a maximum. In the latter case, however, bowstring lattice girders were employed, all the others being of the usual plate-built type.

The *Flooring* between these girders was of Mr. Hobson's hydraulic-pressed arched plate or trough description, which combines great strength with lightness, and reduces to the utmost the amount of riveting, besides being water-tight.

When the *Columns, Girders*, and *Flooring Plates* were erected in position, a very substantial structure was the result, the laying of the sleepers and rails being the next operations previous to finishing off various minor details too numerous to mention.

The *Permanent Way* consists of 56 pounds per yard flat bottomed steel rails, spiked to longitudinal timber sleepers, which are keyed to the arched flooring beams as shown in the view of a portion of the line on page 506.

The *Electrical Conductor* consists of a steel ⊓ bar, weighing 40 lbs. per yard, placed midway between the rails of each line, and carried on porcelain insulators supported by cross-timbers between the sleepers, the joints of the bars being provided with copper fish-plate connections. As the return current passes through the rails, a bent iron bond is riveted to the ends of two adjacent rails at each fish joint, cables, laid underground from the railway to the generating station—a distance of 60 yards—connecting the conductors and the rails with the dynamos.

The central conductors on the up and down lines are

electrically connected at each of the thirteen cross-over roads, as also are the ordinary rails, thus making a network of the conductors, and removing the chance of one faulty connection interfering with the working of the line.

The *Collectors* for taking the electricity from the central rail and delivering it to the motors consist of cast iron shoes 12″ in width, loosely hinged from an insulated block at the end of one bogie of each carriage.

The design of the *Rolling Stock* had to be very carefully considered as regards weight, convenience, etc., but eventually resolved itself into cars of the American double bogie type, each of which has seat accommodation for 16 first-class and 41 second-class travellers, a passage extending from end to end of the train, with the driver's box at each extremity. The *Motors* are operated by the driver, who travels at the front end, changing of course to the other end on arrival at the terminus, thus avoiding all shunting or uncoupling of the trains.

Each train has two motors, one fitted on the leading bogie of the first carriage, and the other on the trailing bogie of the second carriage. The armatures are of the drum class, mounted directly upon the axles, the magnets being series wound, of the double horse-shoe type, supported by two bearings on the axle, and also by a special arrangement of springs at the end of the magnets from the bogie framework.

When stationary, and a current of 80 ampères is passed through the motor, there is a torque effort on the rim of the wheels of 1,060 lbs, or with 100 ampères, of 1,400 lbs. The dimensions and winding have not been arranged to give the maximum efficiency at full load and speed, as only for a very few minutes each journey will full speed be attained, most of the time being employed in starting and

accelerating the train, the maximum speed, however, attained by the motors will be 300 revolutions per minute, equivalent to a train speed of 30 miles per hour. The carriages are lit with incandescent lamps, supplied with current from the centre steel conductor, the same as the motors.

All the stations are lit with incandescent lamps supplied from accumulators fixed underneath the platforms, which also supply current for working the automatic electric signals operated by the trains themselves. These accumulators are charged in series from the main dynamos at 500 volts.

Another most important feature of the undertaking was the location of the *Generating Station* with a view to the economical and convenient coal and water supply, and also to its somewhat central position on the line, which in every case was fully obtained. The site selected was below the arches of the coal railway of the Lancashire and Yorkshire Railway Company at the Wellington Dock, the fuel being thus delivered direct from trucks on the line into large hoppers placed over the boilers, which are six in number, and 8 feet diameter, by 30 feet in length. From the hoppers the coal is conveyed without any handling whatever to the furnaces, which are supplied with Messrs. Vicars' mechanical stokers, an economiser in the main flue utilising the waste heat of the escaping gases for the purpose of raising the temperature of the feed water.

The engines—by Messrs. John Musgrave & Sons—are four in number, each being a 400 horse power horizontal compound, fitted with Corliss valves. The cylinders are 15½″ and 31″ diameter, the stroke being 3′ 0″, and the working steam pressure 120 lbs. per square inch. The exhaust steam from three out of the four low

pressure cylinders is led into one condenser, the circulating and air pumps being rope-driven by a small Musgrave vertical compound engine, somewhat similar in design to that shown on page 444. The whole of the condensing machinery is in duplicate, and the main engines and boilers so arranged that one of each may be disconnected at any time for repair or examination.

Each pair of main engines drives, by means of 19 cotton ropes 1¼" diameter, an Electric Construction Company's shunt wound two pole dynamo, from which the current is conveyed along each line of the railway by the steel conductor previously described. Hinged collectors of cast iron, sliding upon this conductor, allow the current, when required, to pass through the motors and to return by the wheels and rails to the dynamos, each of which is capable of giving an output of 500 volts 475 ampères, at 400 revolutions per minute. These machines have drum armatures and magnets of the double horse shoe type fixed vertically, the latter being cut through on the horizontal centre line so that the top half can be taken off, and the armature taken out by a direct lift, without disturbing the bearings.

As the late Mr. Greathead, one of the engineers of the line, emphatically pointed out, there are tractive features of great interest connected with this railway, its electric motors weighing only 20 per cent of the total weight of the train exclusive of the motors, whereas on the Metropolitan Railway of London, the steam locomotives weigh proportionately double. On the other hand, the tractive effort of which the electric motors are capable is, in the case of the Liverpool Overhead Railway, 120 lbs. per ton of train, compared with the similar 71 lbs. of the above engines. And further, not only can a much greater tractive force be

obtained by electricity, but by adopting motor-carriages an adhesion is obtained which amounts to 115 lbs. per ton of train, whereas on the Metropolitan it is only 61 lbs. Lastly, the relative tractive forces per ton of motor and locomotive are very striking, since on the Overhead line electricity gives 730 lbs. tractive effort per ton of motor as a maximum at starting, whilst on the Metropolitan this force is only 234 lbs. per ton of locomotive, or less than one third of the above.

The question of the relative economy of working by steam and by electricity is so important that the greatest care has been taken to ascertain the true bearings of the case at every point, as so many things require careful consideration before a true estimate could be obtained.

One of the conditions of the contract was that the Electric Construction Company of Wolverhampton, who supplied the electrical plant, should run the line themselves for the first two years at the rate of 4d. per mile for traction. As this proved an advantageous arrangement for the Company, who watched every movement connected with the line under the supervision of their Engineer-in-Chief—the information so kindly supplied to us should be of special value.

There are other things besides fuel consumption that influence the economy of working any railway, and these include general supervision, motor and train wages, oil, waste and grease, water, stores and sundries, cleaning and repairs of the rolling stock, etc., but so admirably has this line been planned and managed at every point, that the total working expenses now amount to the extremely small sum of about 3½d. per train mile for traction.

It may here be added that the generating plant is capable of running a three as well as a five minutes'

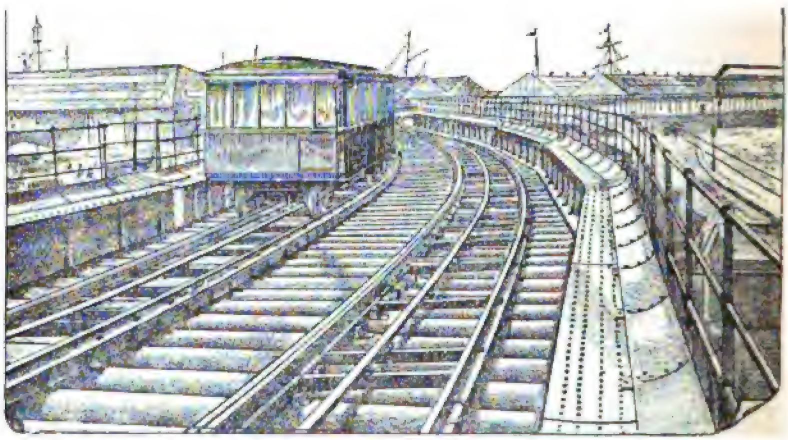
service of trains over the whole length of the line, and these perform the journey of fully six miles in 30 minutes, including a stop at each of the 14 stations, each train, complete with motors, and with full complement of passengers, weighing nearly 40 tons. The working staff is very small, and the fares uniform, that is, 3d. first class, and 2d. second class, either for a whole or for a partial journey, however short.

When it is considered that this line was literally threaded through a very complicated system of cross-over roads, dock lines, warehouses, and existing railways, with the engineers tied down on every side by the authorities, it is a wonder that the permanent structure has been so well and so simply arranged. On the other hand, so carefully was all the rolling stock and working machinery designed and executed, that since the opening day, February 4th, 1893, everything has gone with the utmost regularity.

Having pointed out the various technical excellencies of the Overhead Railway, let us now show how it is appreciated by the public. When the dock length of five miles was opened for traffic the passengers consisted chiefly of people on business and visitors to the city. When, however, the one mile extension to Seaforth Sands came into operation a very large increase of traffic resulted, residents in their thousands from Liverpool, Birkenhead, and their surrounding districts at once availing themselves of a delightful and cheap method of transport to the seaside. Further, by the recent extension of the opposite end of the line to the handsome residential localities of the Princes and Sefton Parks, another great increase of traffic has taken place. From its elevated position, as shown on next page, an unobstructed view of the streets, docks, shipping, river, and the beautiful scenery beyond can be had from

end to end. The motion of the carriages is remarkably smooth, the maximum gradient one in forty, extreme speed 35 miles an hour, and as an almost daily user of the line since the opening, I can myself only speak of it generally in the highest terms, many of the perhaps choicest passages in this volume having been very comfortably sketched out, developed, proof-corrected, etc., during transit from point to point.

One of the most curious features of the carriages is



LIVERPOOL OVERHEAD RAILWAY.

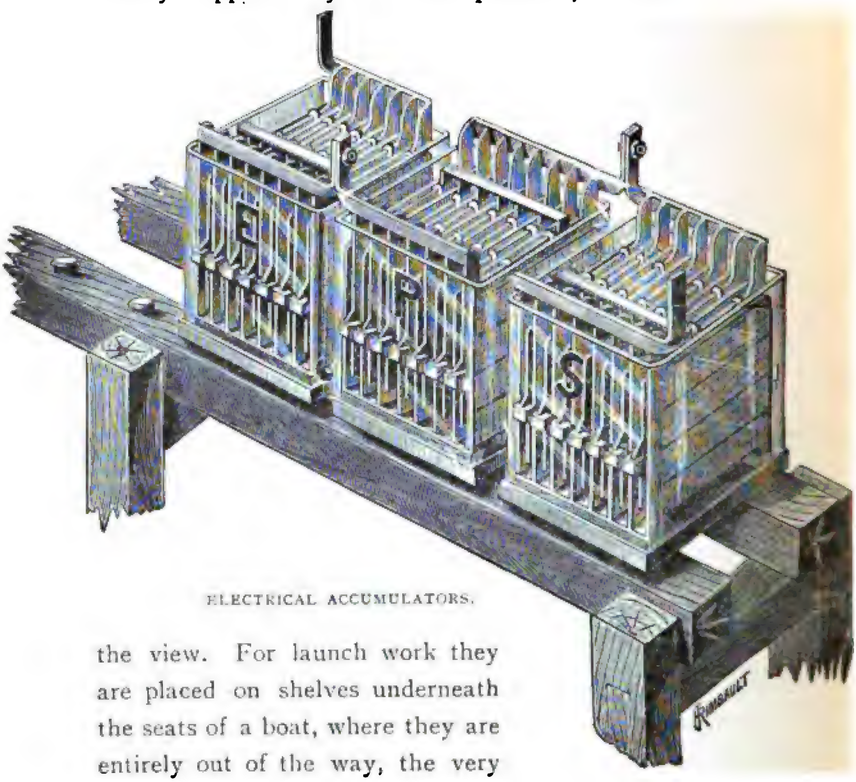
their invisible propulsion, as if, indeed, by the wind. Nothing, however, that we may say can be so touchingly expressive as the remark of a distinguished Celestial, as reported by the ever genial managing engineer Mr. S. B. Cottrill. Upon seeing the trains in motion for the first time the former enthusiastically exclaimed "Hah-ah-ah! no pullee!! *no pushee*!!! BUT GO-EE!!!"

Amongst those who took the initiative in promoting this grand scheme may be mentioned Mr. A. G. Lyster,

the Engineer to the Mersey Docks and Harbour Board, and Mr. Alfred Holt, member of the Board. The chief engineers of the undertaking were Sir Douglas Fox and Mr. J. H. Greathead, the Electric Construction Company acting as electrical constructors, whilst Messrs. John Musgrave & Sons supplied the main driving machinery and its connections, to which reference has already been made, and Messrs. Hick, Hargreaves & Co., similar machinery for the recent extension at the power house, which has also been described. The railway has become very popular and has not only proved a profitable enterprise but promises to be still more so as time rolls on.

As the Hydraulic Accumulator is to the Hydraulic system a reservoir of power for instant use at any time, so is the *Electrical* Accumulator, mentioned on page 502, to the *Electrical* system; hence, launches on rivers, and vehicles, etc., on land, which require intermittent supplies of motive power, can have them by this means. To describe them in scientific language would occupy too much space, and be, at the same time, unattractive to many readers. Perhaps, however, it may be sufficient for the purpose to show on next page a detail view of three of these accumulators in glass boxes, by the Electrical Power Storage Co., of London. From this it will be seen that they consist of pasted lead plates standing in receptacles, which may be either of glass, ebonite, wood lined with lead, or lead, to suit the various uses for which they are required. For isolated installations and for motive power purposes, where the battery may be stationary, they are usually put into glass boxes; for purposes where weight is of considerable importance, ebonite is used; for ship use, however, wooden boxes lined with lead are found to be the most convenient. Those in lead boxes, on the other

hand, are chiefly employed for the larger supplies of electricity, as given from Central Supply Stations. The cells, when in position, are capable of being connected together, as shown, in smaller or larger numbers, according to circumstances, and in stationary installations are usually supported by a timber platform, as exhibited in



ELECTRICAL ACCUMULATORS.

the view. For launch work they are placed on shelves underneath the seats of a boat, where they are entirely out of the way, the very compact little engine at the stern propelling the vessel, and thus leaving the whole of the space available for passengers. These accumulators are made in various sizes, portable or otherwise, and prove useful accessories in Electrical Engineering, as they can be so easily charged and practically applied.

It is difficult at present to say what electrical power transmission is now coming to, especially over long distances, and in hitherto untrodden paths. "Coming events cast their shadows before," and much indeed may be gathered on this subject from recently accomplished works on a prodigious scale, in which—at Niagara, Fresno, Utah, and other places—the talent of the Westinghouse Company and the General Electric Company, etc., of the United States, and the Hydraulic power fraternity of all other States, has been so combined as to produce marvellous results. Amongst other valuable Electrical projects in view for extended application is that by Messrs. Keith & White for wreck-raising from depths in which it would be impossible for divers to work.

This is accomplished by means of specially constructed Electro-magnets, which can be made to have any required lifting power. In the case of H.M.S. *Victoria*, now lying in 80 fathoms of water, it is proposed to employ a sufficient number of 120 ton power magnets attached to steel wire ropes, and these, automatically seizing the hull at numerous points when lowered, are expected, by the use of hydraulic appliances, to raise the ship nearly to the surface in stages, and thus allow her eventually to be beached.

For some time past the system has been in very successful and economical operation in connection with electric cranes, the magnets automatically gripping the objects to be lifted and similarly allowing them to be deposited at the required spot without the aid of slings.

CHAPTER XXVIII.

PRIMARY AIDS TO SUCCESS IN RAILWAY ENTERPRISE.

Considerations initially affecting the success of a Railway—Its Commercial Planning—How to build a good "Prospectus"—General knowledge of a New Locality—Utilisation of Natural Resources—House Building—Simplest Methods of obtaining Water—Norton Tube System—Forces of Nature as Water Raisers—Wind Wheel Power—Water Wheels—Treble Barrel Ram Pumps—Pelton Wheels—Their Special Application—Turbines and their Modifications—Other Water Motors—How the Fluid Supply affects a Country—Transatlantic Examples from Practice—Splendid Results.

THROUGHOUT this volume we have endeavoured not only to describe the peculiar features of railway engineering and the mechanical methods that conduce so much to its success, but also a few of the commercial aspects of the case from various points of view. In all these particulars we hope we have been intelligible to our general readers, to whom a few side lights upon such matters may have been acceptable.

In this chapter, we further intend to show how other considerations of a most important nature add very materially to the success of a line, or combinations of lines on the grandest as well as on the most ordinary scales. By these we hope to show how, by means of engineering science skilfully employed, the resources of a country may be utilised for the benefit of nations as well as of its own inhabitants, and also by the railways provided for their comfort, convenience, and prosperity. Although

it may be a fine thing for a great engineer to achieve wonders from a technical point of view, we think that the summit of perfection in the eyes of the people will lie entirely in *commercial* results, and this being so we shall proceed to show how some of these can be best attained.

As in early days, the *Prospectus* holds a most important position, inasmuch as it shows to people generally the leading advantages of the proposed line, and induces them in large numbers to become shareholders in the undertaking from the outset. Of course, this document must be true and faithful, as well as attractive, in every respect, otherwise many will be disappointed, as they were to a gigantic extent during the railway mania of the "forties."

Now how is this to be accomplished? In many ways. Geographical and climatical knowledge of a country will primarily do much for a new line on new territory, but perhaps one of the most powerful methods of doing it is to show how the resources of the country can be profitably utilised after the surveyors have pointed out their value and extent. These resources are, in the main, of a mineral and agricultural nature, which require efficient working up by the multitudes whom the proposed railway is expected to draw to its borders.

Having proved to the world how advantageous it will be for people to settle down, in perhaps hundreds of thousands, in the new territories, it becomes advisable for the Company to show them in a general way how forests may be economically cleared and utilised; villages, towns, and cities, judiciously planted and built; how their inhabitants are to be supplied with water; cheap motive power obtained for manufacturing purposes; and so on in various other respects. As a rule, prospective shareholders require to have these points brought authoritatively

to their notice before they will pay much attention to them—for obvious reasons.

After the supreme advantages of the country and climate have been clearly exhibited, it may be well to indicate the house building powers of the region, which vary in accordance with either more or less abundant and convenient natural supplies of timber, or none at all, as on the boundless prairie. In the first case there is no difficulty, but if timber cannot be had, corrugated iron houses, such as those made to suit all climates, will be found advantageous, as the details, complete in every respect, ready for erection, can be so easily transported over long distances, put together, and afterwards taken down and re-erected in another locality with little trouble if required. Although timber is, in the main, the basis of colonial edifices, the iron structures we have mentioned frequently prove acceptable, as not only dwellings, but churches, warehouses, hospitals, sheds, etc., can thus be so easily and cheaply provided.

It is not perhaps too much to say that the *want of water* has often proved an insurmountable drawback to many a promising region, and therefore, if there is no convenient supply to be had from a river, or lake, what then is to be done? The place forsaken? No, or at least not until further investigation has been made. Many years ago our troops on the plains of Abyssinia suffered greatly from want of water. Fortunately, Captain Norton conceived the happy idea of boring a small hole into the sand, when, to his astonishment, a plentiful and continued supply of pure fluid burst upwards.

Since then the *Norton Steel Tube Wells* have been in great request all over the world in places where an Artesian supply is available, thus avoiding the costly

process of well digging with its sometimes contaminated surface water obstacles. Some idea may be formed of the nature of these tubes when we state that their internal diameter ranges from 1¼" to 4", even larger sizes being used for special purposes when needed. The depth of the borings vary from 50 to at least 300 feet, the natural supply of water being from 3,000 to as much as 2,000,000 gallons per day of ten hours, according to the number and diameter of the tubes employed.

Having got the water to the surface in abundance, how is it now to be conveniently distributed amongst the inhabitants of a rapidly increasing community? The same question is quite as applicable to localities where a river, lake, or other sources of supply may be within easy reach, but not available without utilising such primitive appliances as barrels on wheels, etc. Fortunately, this can easily be answered, as, apart altogether from *steam* pumping engines, the power of wind and other motors can be thus employed with splendid effect.

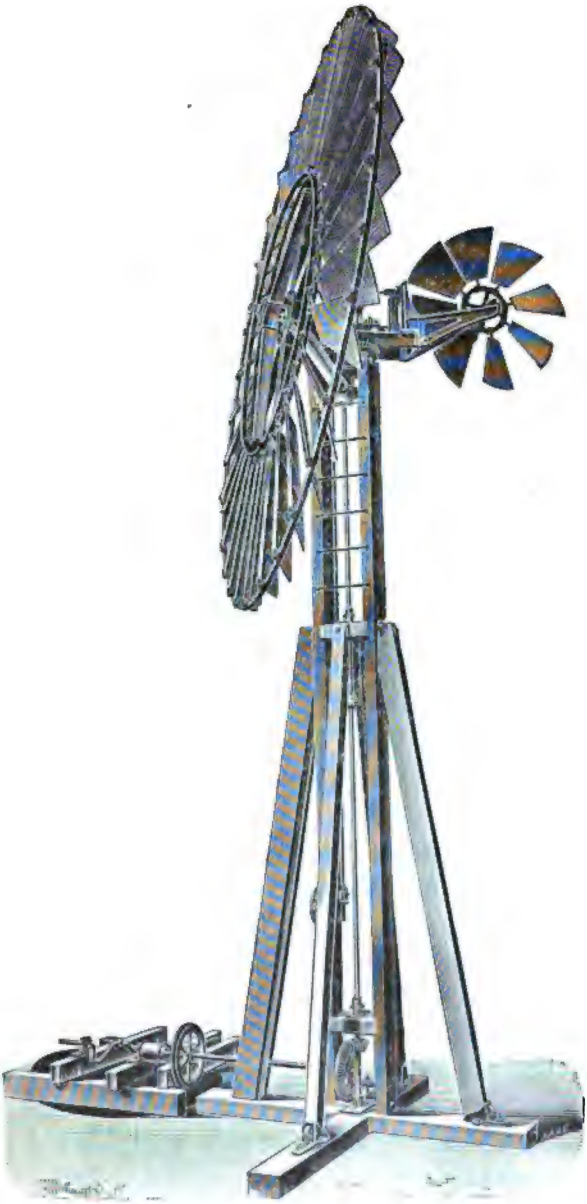
In old countries the water supply is usually taken from artificial reservoirs, or from lakes, whose surface is sufficiently above the highest point of the town to which the fluid is to be carried by gravitation, through perhaps many miles of pipes. This system may be expensive or otherwise, according to natural surroundings, but it has the great merit of cheapness in maintenance and working. In new territories something of a more accessible and much less expensive nature must be done, and hence wind wheels, water wheels, turbines, etc., may be usefully employed in pumping water either into an adjacent reservoir or tank, from either of which the town supply may be easily obtained.

In England, the old style *Wind Wheels* have become

things of the past because steam power is so accessible and convenient. In Holland, however, about 9,000 of them are still usefully employed in pumping water on a national scale, and thus helping to keep the country from being flooded. The old "mill" of Don Quixote celebrity was a circular and costly grinding structure, with four enormous arms, whose sail area was automatically kept true to the breeze by means of a small subsidiary wheel. The modern *Wind Wheel* or *Engine*, on the other hand, as shown in the view on the next page of one of 16′ 0″ diameter by Messrs. Robert Warner & Co., consists of a flat annular ring, attached to several arms, the shaft of which revolves in bearings on the top of a very simply constructed and inexpensive framing or tower, capable of being easily fixed in position, or made portable if required.

The "sails" are either of canvas or of sheet steel vanes, capable of being swivelled on their axes from zero to nearly square with the wind, according to the intensity of the blast, this movement being under automatic control, so that the power developed may be steady. The tail wheel does all the steering, and a hand lever enables the machinery to be kept under the most perfect control for starting and stopping, slowing, etc., as in the steam engine. By the intervention of wheel gear and shafting, as shown, either high lift or low lift pumps of various kinds may be used most effectually and continuously.

The driving wheels of the above are made from 7 to 40 feet diameter, and their efficiency may be gathered from the fact that, while with three throw pumps the delivery of water per hour to a height of 100 feet, with only a ten-mile wind, is 400 gallons for a 16 feet engine, the similar delivery for a 40 feet wheel is 6,000 gallons. The supporting framework may be either in timber for small



WIND WHEEL OR ENGINE.

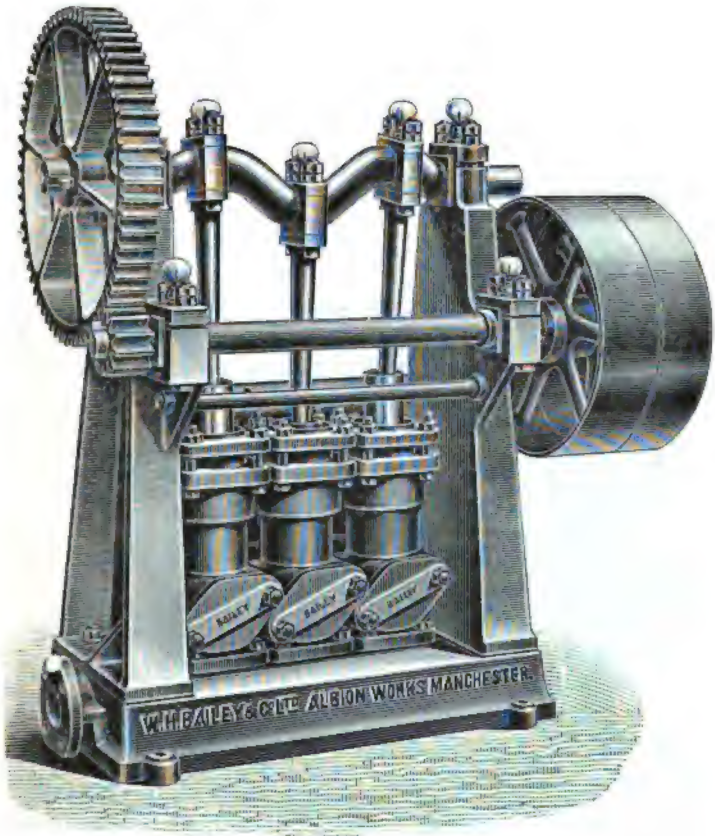
sizes, as shown, or in steel of strong but light construction for large motors.

Wind, thus applied, is the cheapest of all the powers, and although the engines we have described are excellent for village water supply purposes, they can also be used for those of an electrical nature. *Wind and water combined* may be successfully employed for power transmission in various ways. For instance, wind wheels may be used to pump water into a highly elevated reservoir in large quanties, and from this it may descend by gravity through pipes, and thus be enabled to work turbines and hydraulic engines. By means of these appliances, compressed air, high pressure accumulator water, electrical, and a great variety of other work may be done which could not otherwise be performed, owing, perhaps, to the great inconvenience and cost of obtaining steam power.

From this will be seen how the waste and fluctuating energy of the wind may be transmuted, stored up, and applied to many useful purposes. The beauty of the system may be still further gathered from the fact that the wind wheel not only works unceasingly by day and by night without needing attention, but is automatically able to reef, double reef, and furl its own sails in the face of a rising storm, its normal energy being based upon a wind velocity of only 14 miles an hour. Hence may be seen the unique capacity of this improved appliance, which, when once set in motion, works for nothing!

Another extremely simple and inexpensive engine of world-wide reputation is the *Water Wheel* of improved build, which, for colonial purposes especially, is invaluable, since, like the windmill, it can perform gratuitously by night and by day, if needed, very much good work of every description.

These wheels are now manufactured up to 50 feet in diameter, and if for difficult inland or mountain transit, can be made in small pieces to suit the method of transport.

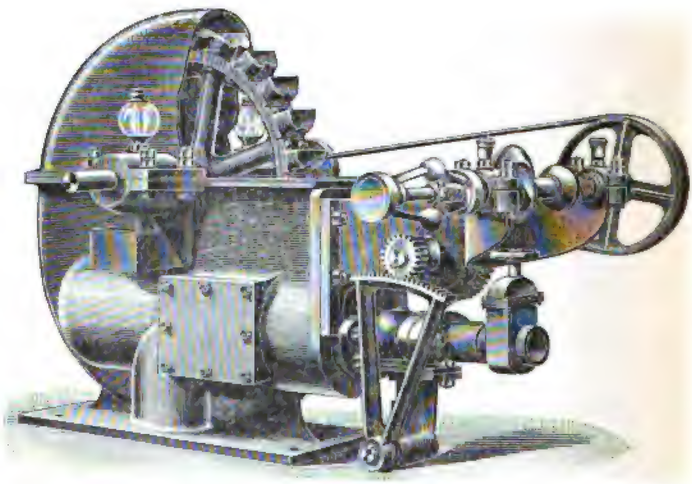


TREBLE BARREL RAM PUMPS.

When used for water raising purposes, *Treble Barrel Ram Pumps* are chiefly employed, a set of which, by Sir W. H. Bailey & Co., is shown above. Here belt power was found convenient, but, to suit varying circumstances, the gearing

can be arranged according to the power of the motor and its method of application.

An important modern modification of the water wheel by Messrs. Carrick & Ritchie is the improved *Jet Water Motor,* here shown with casing partially removed, which is capable of developing great power in small compass with water pressures up to 2,000 feet head. The machine as a class, is in great request throughout the globe,

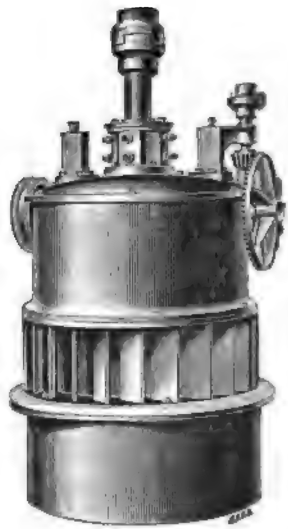


JET WATER MOTOR, ON "PELTON" PRINCIPLE.

especially in mining districts, and has had recent improvements made upon it, one of which consists in the application of a conical nozzle to the interior end of the supply pipe, in such a way as to allow the hand wheel to adjust to a nicety the admission of water, and thus with great ease start, stop, or otherwise control the movements of the engine, which are automatically regulated so far as variable load requirements are concerned by means of the governor.

This motor, on the "Pelton" principle, is made of all sizes from 6″ to 6′ 0″ in diameter, the framing and casing being made of timber or iron, according to circumstances, and to give some idea of the power of the machine it may be mentioned that the wheel shown in the view is 21″ diameter, and under a 250 feet head of water is capable of producing 16 horse power at 692 revolutions per minute.

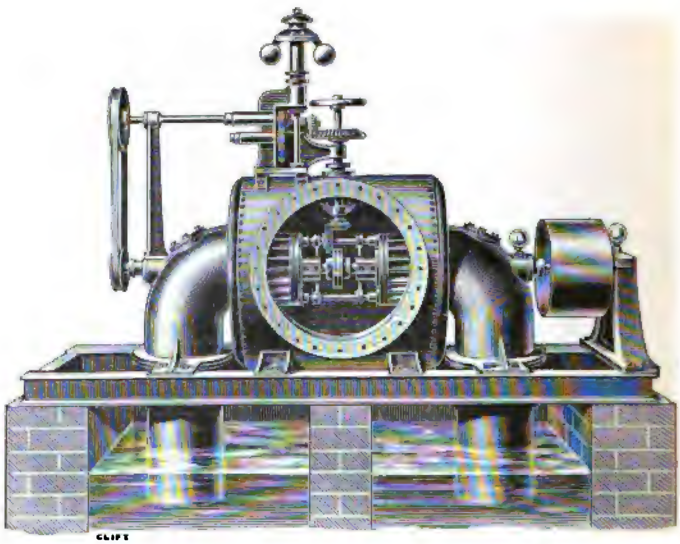
Another valuable hydraulic motor is the well-known *Turbine*, which is now used on a colossal scale. The operation of this engine is invisible, the action of the wind, however, on the sails of a wind-wheel, or on the vanes of some ventilators, will help to explain the method of applying fluid force to it. The weight of a column of fresh water 12″ high and one square inch area, is ·434 lb., say half a pound approximately, hence, with a column of fluid 100 feet in height resting upon the whole exposed vane area of a turbine, and producing a pressure of 43·4 lbs. per square inch, it is easy to see that considerable power can thus be given out, especially when aided by scientific design and construction.



"VICTOR" TURBINE.

Another vital point in this engine is its extreme compactness and simplicity in construction and erection, as may be gathered from the above view, illustrating one of Mr. F. Nell's "Victor" type of turbines, as now employed in some of the largest installations in the world.

The engraving shows the exterior of a turbine, ready for setting in a masonry or brickwork well, the main vertical shaft transmitting power, the small one being used for regulating the admission of water to the interior. When of single or duplex horizontal formation, the turbine may be placed on a bed plate upon the ground level, and cased in with plate iron, the pipes being similarly made;

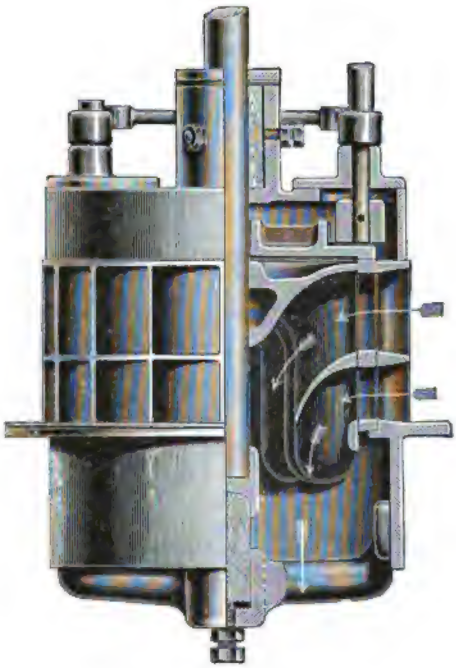


DOUBLE DISCHARGE HORIZONTAL TURBINE.

all the parts being most convenient for practical use, and easily accessible for examination or repair.

The *Double Discharge Horizontal Turbine* of Messrs. Carrick & Ritchie, for falls of 10′ 0″ to 50′ 0″, with its starting and governing appliances, is shown on this page. Here, for example, two 9″ wheels, with 50′ 0″ head of water and 955 revolutions per minute, produce a power of about 42 horses either for belt or for wheel gearing. With the object, however, of economising water when the supply is

limited or extremely variable, the same firm have designed their new *Double Gate Turbine*, illustrated below, the sectional half of which shows its internal arrangement. As it is not always expedient to have two engines of different sizes to meet the summer and winter supplies,



DOUBLE GATE TURBINE.

the division of the wheel into two portions, by means of a curved diaphragm, as shown, enables the greatest economy to be obtained, one of the supply openings being either partially or wholly closed, according to circumstances, whilst the other is full open.

One of the most interesting applications of the turbine, on a colossal scale, is to be found at the Niagara Falls

electrical installation power-house, which contains ten 5,000 horse-power dynamos, each of which is driven by a vertical duplex turbine only 5 feet diameter, placed at the bottom of a well which gives a head of 178 feet. It may be added that, to relieve the footstep bearing of the weight of the vertical shaft and revolving portion of the dynamo carried by it, each turbine is so arranged on the equilibrium principle, that while the total downward load is 152,000 lbs., it is sustained by an upward pressure of 149,000 to 155,000 lbs., according to the quantity of water used at the time. This class of engine, though not very much employed in England, is extremely popular in Switzerland and other continental and transatlantic countries where a suitable water supply is easily obtained.

Passing onwards, we come to another class of *Water Motors* which perform gratuitous work by day and by night, as shown in the foreground of the landscape view opposite. These are of the duplex pump description, by Messrs. Tangye, the cylinders of which are 6″ diameter, and the rams 1½″ diameter, the stroke of all being 6″. Small as this installation certainly is, it nevertheless delivers a supply of water to the village of Illogan, through pipes of 2″ bore, one mile in length, and to a total vertical height of 240 feet. The driving supply flows through pipes from a point sufficiently up the river to give a working head of 42 feet, the suction being taken from the pool in the foreground.

As another example it may be mentioned that the Brighton Water Works Company employ a similar ram pump, worked by the water which passes from one elevated reservoir to another below it, the waste fluid passing onwards to the town. This engine is of sufficient size to drive water through 1,600 yards of 6″ pipes to a reservoir

239 feet above it, and through an additional 1,217 yards of 4" pipe to another reservoir 40 feet higher.

APPLICATION OF WATER DRIVEN DUPLEX PUMP.

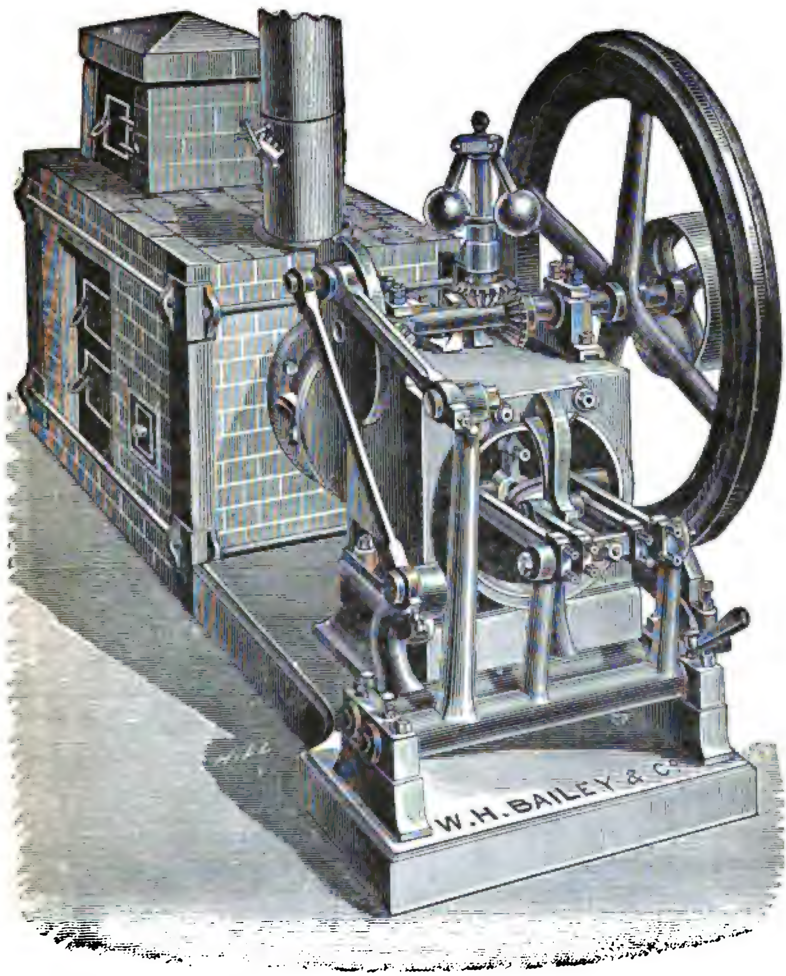
These machines are now made in many different sizes,

beginning with a capacity of 300 gallons delivery per day of 24 hours, and ending with 200,000 gallons in the same period, the heights of lift being suited to the amount and pressure of the driving water, which bears a very small proportion to the quantity delivered.

It may be useful here to note that in aid of these projects, by avoiding expense and inconvenience in the transport of iron pipes to regions difficult of access, the Far West people sometimes manufacture them for themselves. For instance, only recently, at a point in the Rockies, 8,000 feet above sea level, a set of 200 horse-power hydraulic engines were supplied with water passed for a distance through thin plate-iron pipes rolled to shape, and punched and riveted together on the spot by means of portable plant. A still simpler method in use is to make the pipes of sawn battens, strongly bound with iron hoops in cask fashion, and break-jointed at the ends to secure safe continuity of length, thus enabling a scheme to become possible when otherwise it might be impracticable. As a splendid example of these it may be added that, for the hydraulic driving of the great Utah Electric Power Transmission Works, now in progress, water is carried for five miles through wooden pipes, 6′ 0″ diameter, riveted plate steel pipes of the same diameter being used for the rest of the distance.

Hitherto, we have spoken only of wind and water motors, but in regions where the former is usually light, and the latter not suitable, and even the steam engine with its accessories inapplicable, some other power must be used. Here, the *Hot Air Engine* comes to our aid, an engine, too, which has worked with great success and economy at home and abroad where small powers were needed for various purposes.

A view of one of these engines complete is shown here, and from this a good idea of its general working



HOT AIR ENGINE.

may be gathered. The motor itself consists of a cylinder closed at one end by a steel pot, and at the other by a

piston, the former being fixed within the stove, whilst the latter is surrounded by a circulating water jacket supplied with fluid from any convenient source. The engine is kept solely at work by the alternate heating and cooling of the air within the cylinder, the air being caused to travel backwards and forwards by a loose fitting piston, which is worked from the outside by means of a rod passing through the front or driving piston, no valves of any kind being required.

The stove is provided with a furnace capable of holding enough fuel to keep the engine going from three to six hours without stopping, coke, coal, peat, wood, etc., all coming in useful for firing, the attention needed being so simple that any intelligent labourer or household servant may easily learn to work it.

After the foregoing remarks upon the *Water Question* some may ask what it has to do with railway enterprise? Much in every way, but primarily in a threefold sense, as follows:—

Firstly, because the prosperity of a community, a province, or even a whole country, depends greatly upon a water supply that may either make a desert smile, or, through the want of it, cause its sterility and uninhabitable nature to remain.

Secondly, because we have thus had the opportunity of showing how the *waste* forces of nature may be profitably utilised, forces, too, of immense value only now becoming fully appreciated on stupendous scales, and under new phases, for the benefit of nations.

Thirdly, because after illustrating how modern machinery, with these forces as prime movers, can be made to raise water gratuitously, for town and country supply, we have endeavoured to explain how these same machines

may be used for motive power purposes too numerous to mention.

With these facts in view, and also that the *Prospectus* of a new railway company is the thing wherewith to awaken the interest of the public, we believe that if this document shows clearly the advantages its adjacent territory will possess when opened out by the skill of the engineer, with all the best modern appliances at command, the results should be of the most satisfactory nature to all concerned, especially when the future inhabitants learn for themselves the art of perhaps enormously increasing the value of their cheaply purchased land. The Canadian Pacific enterprise has already exhibited how this can be done, but later facts are available which will still further confirm the above remarks.

Recently, an arid tract of country in South California had its value assessed at 75 cents per acre. When brought under irrigation, however, the price rose with a bound, and purchasers were found at 100 dollars an acre. Still further improved, the selling price of the land went up to 500, and then onwards to 2,000 dollars an acre, and even at this rate produced a 50 per cent. dividend! If, then, what has been successfully accomplished in America and Canada is done in other parts of the globe where possible, may we not anticipate great benefits not only for railways in prospect, but for those already in existence, where much may be done that at present remains undone ?

CHAPTER XXIX.

OPENING OF THE DEEPHAVEN AND BATHURST RAILWAY.—RESULTS.

A Great Day for Baratania at hand—The People jubilant—A "Most Awful Disaster" on the Line—Its Effects upon the Inhabitants—Upon the Technical Staff—Cause of the Accident—The Opening Day—"Gr-r-reat Excitement" everywhere—The Governor and his Lady again "Bossing the Show"—Enthusiasm of the Directors—The Festivities—Line open for Traffic—Its Great Popularity—Prodigious Development of Deephaven and Bathurst—The Engineer's Advice regarding proposed Extensions—The Author's experiences of Engineering Practice—Hints for Beginners—Prospects of Future Success—Final Remarks.

A GREAT and historical day for Baratania is now close at hand. In previous pages we have sketched out the discovery of the Island; the pioneer movements of its inhabitants; the cutting of the First Sod of its initial standard gauge railway, and the various operations that followed, so that as a picture from life in a new country, or even in new parts of an old country, the descriptions given may be rendered attractive to all. Everything has been carried out and Board-of-Trade-tested and inspected to the entire satisfaction of Sir Julius Greville, the Resident Engineer, the Contractors, and everybody else, especially the inhabitants, all of whom had taken a warm interest in the undertaking from the commencement.

A spirit of jubilation has pervaded the minds of the people for the last week, intensified, of course, by the official announcement that "within a month the line will be opened for traffic." On the following day a tornado

burst upon the Island and did much damage. By sunset calmness reigned, but about 9.30 the silence of the streets was broken by the discordant shouts of the newspaper selling fraternity who announced a "most *awful* disaster on the railway, many killed and *wownd*ed—gr-r-reat excitement," and so on, which so alarmed the townsfolk that exclamations such as "Good gracious!" "How sad!" "Dear me! is it possible?" etc., were heard on all sides, whilst anxious enquiries were made to the right, to the left, and in every other direction. Late in the afternoon a man had been seen running full speed towards the house of the resident engineer to report the calamity.

"Anything wrong?" hastily exclaimed the editor of *The Deephaven Herald*, as he tried to intercept him.

"Serious accident on the line."

"Anyone killed?"

"None killed."

To the former this appeared to be *nine* killed, and so he logically concluded that many must also have been injured. With these facts as a basis he swiftly composed an article for the *Evening Special* which would give the anxious crowds some idea of the state of affairs, not, of course, as they really were, but as he himself thought they might, could, would, or should have been to produce such dire results, leaving, however, the corrections to be made when the whole truth became known.

Next day the amended news read as follows:—"During the terrible storm of yesterday a portion of the nearly finished Braemar viaduct was carried away. No lives were lost, nor, indeed, was anyone injured. We have just been informed that the damage is so trivial that the contractors hope to complete the structure within a few days."

Now, how did this accident happen at all, when so much

care had been bestowed upon the work? Mr. Brassey experienced disasters of similar nature from pretty much the same causes, on one occasion to the extent of £50,000; and the early Brunel was *just* saved from a worse experience on the Great Western line when constructing it; so let us explain the reason of the Baratanian failure. Messrs. Brown & Jones had been pushing on the works with all speed, and at the same time most successfully. According to the specification, the mortar used in the various erections had been made of the "lime of the country," and this had hitherto proved suitable enough, although not the best for quick setting. Here, however, the last portion of the above viaduct, which had been built during wet weather, was overtaken by a most violent tempest before the mortar had sufficiently consolidated, the result being that a small portion of the work most exposed to the fury of the storm gave way.

When the "Resident" and Mr. Brown had carefully surveyed the extent of the damage, the latter immediately put some of his best hands upon the work by day and by night until it was completed. A few days afterwards it was officially announced in the *Herald* that, "As the line will be opened for traffic next Thursday, we hope the day will be kept as a general holiday." This editorial recommendation, however, was quite unnecessary.

"Call me early, call me *early*, mother dear, for tomorrow will be the happiest, merriest, brightest day in all this glad new year," was the expressed wish in many a Baratanian home the night before the great event. The morrow dawned in sunshine and splendour. Everyone was on the move from every point of the compass, so much so, indeed, that it was evident something unusual was going to happen.

Immense preparations had been made to render the scene as impressive as possible. Flags were flying in all directions on land, and the ships in the harbour were profusely decorated in the same manner. The town's folk were already occupying the best positions. Three-mile-an-hour bullock drays were coming in from the country crowded with people in their Sunday best. One horse vehicles, laden with whole families in go-to-meeting costumes were similarly approaching the capital. Farmers, etc., on horse back, and vast numbers of pedestrians were merrily heading for the same spot. On they came in their thousands, until at last the incoming tide had reached its full height.

The tops of the houses, the trees, and every eminence that could allow the train to be seen to the best advantage, as well as the terminus and its approaches, were packed with sightseers. All along the line, too, people were in waiting at the various points of interest, while Bathurst city was in a state of flutter all over, as that was not only to be the end of the outward run, but the scene of the accompanying festivities. Special privileges had been provided for many favoured guests, each of whom was to receive an elegantly ornamented card souvenir.

The hum of many voices—the bustling activity of policemen and railway officials in their new uniforms—the great variety of crowded vehicles drawn up in lines—the train of handsome carriages—the locomotive, fresh from the builder's hands, adorned with flags and evergreens, and the gaily dressed passengers who are now taking their seats for the first time, presented a scene which compelled the talented editor of *The Herald* to confess next day his "utter inability to describe adequately."

When all was ready, the starting signal was given to

the engine driver, Ronald Macgregor—late of Crewe—and at once the *Sir Sancho* began to move along the line, to the enthusiastic delight of all, and amidst the waving of hats and handkerchiefs and the cheers of the multitude, the first train left Deephaven on its way to the interior, Bathurst being reached in good time after a smooth and most successful run, which, however, had been insured by means of the preliminary trials which brought everything and everybody into good working order at the outset. From the foregoing remarks the reader can easily fancy the scene at the inland terminus at this moment, the phrase, "unbounded enthusiasm on all sides," will, however, express all we wish to convey on this point.

"The banquet?" Ah! that *was* a triumph in every sense. Sir Sancho and his lady were brilliant, Sir Julius Greville was delighted with everything, but in that modest style which indicates true greatness. The Chairman of the Directors seemed to fully recognise his position as the Head of the Clan, and in simple, humorous, and well chosen language, let everyone know how "satisfied *he* was with the proceedings, and how much he anticipated a highly successful future for the line they had now opened. In England," he continued, "the safest occupation of all is railway travelling, but here, in Baratania, it would not only again be the safest, but the most *delightful*, as he and his colleagues would endeavour to make it."

Some of the Directors, and others, including the "Resident," the Locomotive Superintendent, etc., had each something good to say, and when all was over, the company re-embarked in the train to return to Deephaven, and thus ended a day ever to be remembered in that exquisitely beautiful and happy home of the future for everyone.

Were the Chairman's expectations realised? They were—beyond conception. The line soon became extremely popular, Deephaven and Bathurst went up with a series of bounds. Mining and agricultural districts were opened out, more or less, in the vicinity of the line. The nucleii of prospective towns and villages were formed along its borders, or within easy distance of them. Trade marvellously expanded. The timber wharf accommodation was much extended. Messrs. Clark & Stansfield's floating dock, which had done good service in the past, was supplemented by a spacious graving dock. Marine and locomotive repairing works on a small scale, but upon Crewe lines, with plenty of room for future enlargement, were rapidly proceeded with. New gas works were built and water works constructed; in short, nothing was left undone to increase in every way the prosperity of the Island which we have made the scene of all the above performances. The result being that before long, the Engineer-in-Chief was requested to make surveys with a view to extensions of the railway he had so successfully inaugurated.

From some time previous to this, however, Sir Julius had been critically surveying every movement connected with the Light Railway question at home and abroad. The Barsi 2′ 6″ gauge undertaking, and others as well, had been riddled through and through by his keen, logical, and practical reasoning powers. Their defects, their advantages, their construction, their traffic, and, above all, their financial results had been most carefully compared and considered. He knew that the standard 5′ 6″ gauge railways of India were much too expensive to admit of the wished-for development, and that, while the average cost of the mètre or 3′ 3⅜″ gauge lines in that country was less

than one-half of the former, the 2′ 6″ gauge railways cost only one-fifth, including rolling stock and all capital outlay. Their usefulness and profitable working were also of the most marked character, owing partially to the fact that they had sufficient stability to carry a very heavy and bulky goods traffic, and, when compared with the others, the greatest carrying capacity per cent. of cost of track.

With this in view, Sir Julius determined to restrain, for the present, the wishes of the directors regarding the proposed extension of their standard line, and recommended instead a series of 2′ 6″ gauge railways, with the object of most fully and economically developing the trade of the country, and acting as feeders to the main line. He also showed the directors that his proposed system could specially adapt itself to the natural features of the country, on account of its great flexibility, and thus save many costly works. By the aid, too, of the most skilfully designed rolling stock, in which Fox's hydraulically pressed steel frames and every other well-matured improvement could be conveniently utilised, he showed how the constructive expenditure could be reduced to the utmost.

He also offered to obtain from the Leeds Forge Company full particulars regarding *their* share of the Barsi contract, and also a preliminary estimate for similar work in Baratania, besides similar information from Messrs. Kitson & Co. regarding the locomotives they specially designed and built for the same railway. All these, upon being eventually placed before the directors, proved so satisfactory that their Engineer-in-Chief was requested to proceed at once with his scheme, and make the best he could of it. His additional instructions were to utilise the most recent safety and other appliances, including Mr.

White's emergency brakes and automatic level crossing gates, etc.

"But, stop a moment," remarks some inquisitive reader; "does Baratania really exist?—because we cannot find it on the Admiralty charts." Well, no, it has not been volcanically raised just yet; at present, however, this beautiful Isle of the Sea is only a mental creation. An engineer is nothing without being imaginative. His grandest works, though executed with profound skill, are originated by his imagination—that is, he primarily fancies he sees an arrangement of machinery, or works of any description, suited to the end in view, which theoretical and practical knowledge combined enables him to develop and carry out satisfactorily in detail; the same process being repeated in countless forms. What makes Sir Noel Paton's pictures so fascinating? Is it not because he has used his imaginative power to convey, in highly artistic fashion, deep, solid truths in a manner not easily attainable by other methods.

High science literature, as a rule, is dry-as-dustily deterrent to every one but professionals; and engineering literature, though sometimes wonderfully clever, is often the most unreadable of all. Hence, in this volume, we have gone off the beaten track, and introduced a little novelty, by bringing up the fanciful Island of Baratania, with its people, its enterprises, and its successes. But if the setting of the picture is visionary, the *facts* of Engineering life and practice are given as they are to-day, and these, dressed up with happy surroundings, will, we hope, prove interesting and attractive to every reader.

Of course, where there is much of an intricate and extremely varied nature to deal with, it is impossible for one individual to do it justice, even after many years of

close application and observation. Hence, I have been compelled to draw extensively upon the assistance of many kind friends, who have specially allowed me to visit their Works, and obtain from them all the latest tit-bits of engineering experience I wished; in every instance, however, these sources of information and illustration have been acknowledged in the text.

Having for a long time experienced so many of the vicissitudes of engineering practice, I may perhaps be allowed to give a few hints to those who intend to enter upon it, and also to those who wish to begin on their own account. As it was with the great engineers of the past, so is it still. A love of one's work, combined with persevering industry and fair ability, *must* bring success at some time or other when the opportunity presents itself. This is only natural. To the ambitious engineers of early days those chances came pretty frequently, and, like sensible people, they used them as steps to the fame and fortune they ultimately acquired.

Probably no apprentice ever had a greater desire than I myself had to learn the various manipulative processes, to study the peculiarities of constructive machinery, and to sketch to dimensions, during meal hours, the details of engines in progress so that they could be drawn to scale in built up form at home in the evening, all of which proved fascinating employment for a long period. As a student still in the field of engineering, let me offer one or two suggestions to beginners which may prove useful.

Firstly, then, it may be taken as a rule that few "young gentlemen" with good financial expectations should enter the profession, unless for mere accomplishment purposes, because they have so seldom the incentive

to the patient, persevering industry which successful practice so imperatively demands. Neither should those of less brilliant expectations, who prefer pleasure to study, and fancy that the required knowledge can be picked up at any time, when, in fact, it is now very much more complicated than it used to be. Amongst my own pupils I have had great variety, some being idle and careless, others industrious, the latter of which were afterwards more or less successful in various ways, from the winning of a University Scholarship to their valued and profitable employment in other spheres of labour.

I therefore conclude that those most likely to obtain good positions in after life are chiefly to be found amongst the ranks of the poor gentry and decayed nobility classes, because, being naturally ambitious, they will make their profession a labour of love, and spare neither time nor trouble in their efforts to gain success. Through life I have found it so in many cases, and it is perhaps equally true that if I had not at an early age lost my father before he had time to make much as a lawyer, I would not have worked with one-half the pleasure or energy I have done from the very outset.

It is now more certain than ever that engineering is one of the most intellectual of the practical sciences, and at the same time the most generally useful of them all. For proof of this we have only to consider what has been accomplished during the past century towards developing the resources of the world. So closely do these affect the well-being, comfort, luxury and prosperity of nations, that there is hardly anything connected with transport or manufacture in their multitudinous, cheap, and excellent forms, that does not indicate in some way or other the skill and enterprise of the engineer.

The *Principles of Engineering Science* not only enter into every nook and cranny of the mechanical world, but they also wondrously permeate the whole of the animal and vegetable creation—the realms of subterranea—the mechanism of the planets and stars—the machinery of the heavens, and the dynamics of the spheres, either as solitary bodies, or as vast independent systems that stud the infinities of space. In all of these of an astronomical nature we have machinery on a boundless scale in perpetual motion, and without bearings or supports, which is inconceivably beyond our highest flights of inventive skill, or even sometimes of comprehension.

Now, how is this grand science to be so mastered as to enable one to obtain fair success in life? Eminent men of the past, Watt, Stephenson, Whitworth, Fairbairn, and others, knew exactly how to do it, and they *did* it, firstly by means of their own talent, and secondly through their unflagging industry which would leave nothing undone that ought to have been accomplished. Those were the heroes of science who sprung the profession out of chaos, and did well in fifty years what the whole world had been unable to perform since the Creation.

When sufficiently experienced, the prospective "eminent" of to-day has more or less excellent positions to occupy as he gets along. He may, for instance, become the managing engineer or director of some vast establishment, or the highly respected locomotive superintendent or engineer-in-chief to a great railway—all providing good incomes. The worst of it is, however, that the gentlemen who occupy these posts of honour, usually retain them for very long periods, and hence there are few changes.

If, on the other hand, an ambitious practitioner has gained enough knowledge, his next move will probably

be to commence on his own account as a civil or as a consulting engineer. Formerly, this was a delightful enterprise, as engine, machine, bridge, railway station, warehouse, railway, etc., designing rolled in upon him, until he eventually became one of the "eminents," many of whom have now departed.

In addition to the above occupations, the consulting engineer of the present may be called upon to undertake *Arbitration cases*, which provide splendid openings for the display of ability and common-sense combined. *Competitive designs* may be entered upon for highly diversified schemes if the prospects are fair enough, all of which provide free scope for the latest and best experience. Purely *Consultative* Practice does nicely by way of change, and here we have fine opportunities for giving advice to clients at home and abroad regarding the most suitable machinery for certain purposes and ways and means of doing everything to the best advantage.

Surveying and *Valuing* are other most important branches, the former of which includes the inspection and testing of machinery, etc., in every possible manner, for the satisfaction of builders and purchasers alike, and also the collection of information upon which to base "Reports" of endless variety. *Land* surveying may additionally be included. Valuing comes handy at any time, but requires special knowledge, not only of the first cost of machinery and materials, but the proper allowances for wear and tear, and also for the depreciation in commercial value due to ordinary and sometimes to extraordinary circumstances.

It may be well to add that amongst our varied occupations may be mentioned that of giving technical evidence in law courts. In the early days of railways, the *Scientific Witness* so held the key of the position that if *he* proved

that a thing should be done it *was* done, provided legal technicalities and commercial considerations allowed it.

As it was then, so is it still, though of course in modified form. The scientific witness is, and always will be—from an engineering point of view—master of the situation, and this, to the initiated, means a great deal. He may have to wait for days in or about a Law Court until his turn comes, but he will nevertheless obtain a good fee, besides becoming favourably known in influential circles.

With all these facts in sight it will be apparent that an engineer in private practice has the power of earning a handsome income from various sources when he has the chance of doing so. It is only fair, however, to say that although to some this may still be quite true, to many these opportunities have now become so attenuated that it would not be judicious for anyone to begin on his own account without having either a little private means, or friends who can provide him with somewhat steady employment. The cause of this has partly been financial depreciation in commerce throughout the world, severe competition, but chiefly the fact that railway, dock, water-work, gaswork, and other great sources of former private practice are now carried out by public Companies with their own staffs of Engineers-in-chief and assistants.

The only way, therefore, to obtain success at any point, is to be ready to seize one's opportunities when they come, and the best method of being prepared for these is to diligently store up, year by year, the cream of engineering practice in the works and elsewhere; to keep private note books filled with memoranda, tables, data, etc., of all kinds for instant application, and to index alphabetically, in similar books, the titles of all the subjects treated in the technical journals, treatises, etc., that may be pro-

spectively useful for reference. I have myself adopted this system through life, and therefore can highly recommend it on account of the trouble it saves, and the confidence it gives in all kinds of work.

Amongst the many happy reminiscences of one's own career, the following will perhaps illustrate the manner in which the ordinary difficulties of every-day life may be overcome. Some years ago, circumstances over which I had no control drifted me into an undertaking for which I had to acquire considerable experience on new lines. I had sufficient engineering knowledge for the purpose, but otherwise was almost a novice, and was thus compelled to feel my way cautiously. In spite of this, however, injudicious movements were entered upon, only to be arrested by people and things, obstacles and disappointments, that seemed to have been unconsciously planted in my path just in time to avert mischief.

On one occasion I forgot to post a letter, but when calling subsequently on the friend to whom it had been addressed, I came in unexpectedly for important hints which would not otherwise have been obtained. When the work appeared sufficiently matured, I requested the co-operation of a firm in London, their disappointing reply, however, enabled me to enter into a much more favourable arrangement with others. In short, these and similar incidents happened at the exact time and place, and in the simplest and most unexpected manner. Hence, the enterprise, which had originally been honeycombed with the germs of failure, proved eventually successful.

Through these, and many other sometimes aggravating incidents, I have not only gained much experience in the field of engineering, but learnt invaluable lessons outside of the profession, which have enriched me beyond the

wealth of nations, and made me one of the happiest of the happy on life's highway.

At the end of my other volumes on *Civil and Mechanical Engineering*, and *Steamships and their Machinery*, I wished every good thing to engineers and others, in every branch of the service, who kindly helped me to obtain special information, and I do so again with great pleasure. The only favour additionally requested from them is, that I may be similarly supplied with particulars concerning their latest improvements, which I shall at all times be most happy to receive.

SUPPLEMENTARY CHAPTER

TO

RAILWAY ENGINEERING

MECHANICAL AND ELECTRICAL

BY

J. W. C. HALDANE, M.Inst.Mech.E.

SUPPLEMENTARY CHAPTER.

TRANSATLANTIC RAILWAY ENGINEERING.

A Special Tour in Canada—The Canadian Pacific Railway practically considered—In Eastern Canada—On the Prairies—In the Rocky Mountains—Descent of an awful Gorge—Selkirk Range, and its Marvels—Planning of a Mountain Railway for 500 Miles—Prodigious Difficulties—How overcome—How Avalanche dangers are avoided—Strange Effects of a 200,000 ton Avalanche in rapid motion — Snow Shed construction — A stupendous Freak of Nature—Triumph of Engineering—Kootenay Mining Regions—A long and steep Mountain Line descent—How accomplished—The Gold Range—Marvellous Cañon Engineering—Building a Road on the face of a Precipice—Special Cowcatcher Trip over the Mountains—Safety Precautions, along the Line—Lake ana Morass Engineering difficulties — Trestle Railway· Viaduct for 25 miles across a Lake—Through the Sea by Rail for 100 miles—Ghastly Western River Story—Terrible Experiences of the Early Surveyors — Constructive features of Mountain Railways — Mechanical Details—Great success of the Canadian Pacific Railway—Grand Trunk Pacific and Canadian Northern Trans-Continental Lines — Vast Extensions everywhere—Invaluable Experience for future "Eminents."

As the remarks already made in this volume upon Railway Engineering refer almost entirely to those systems which are adopted on lines of comparatively easy construction, I now have the pleasure of giving an additional chapter describing Trans-Atlantic practice in some of its most interesting forms, and also the various methods employed for overcoming apparently insurmountable difficulties.

To the traveller in the British Isles there is nothing of a very striking nature to arrest the attention. No

stupendous mountain ranges to climb. No wildly surging glacier-fed rivers to cross on timber trestle bridges. No elongated serpentine bends in order to obtain workable gradients by which to rise to high altitudes in short direct distances. No precipitous mountain sides on the face of which to notch a line, otherwise impracticable, with, perhaps, a deep river hundreds of feet below, and cloud piercing peaks above, whose avalanches and rushing boulders have to be avoided. No cobwebby steel-built viaducts on which, at great height, to pass over wide and deep valleys. No great lakes to cross on piles for the sake of direct transit, not to mention much more of an exciting nature, to suit the taste of the most ambitious engineer. These, and many other similarly extraordinary features of railway construction will be referred to as we proceed.

A short time ago I had the honour of delightfully traversing the Dominion with the kind friendship of the Governor-General, and also of many influential people in the railway, scientific, and industrial world, so that I could gather, as fully as possible, the information I wished. I had the full swing of the country in every direction, and was thus enabled to write a popular volume entitled *3,800 Miles Across Canada*, which has been highly appreciated on both sides of the Atlantic, and also to prepare illustrated lectures on the subject. I thus had every opportunity of studying not only the general features of the country, but the technical peculiarities of its railways, especially those of the Canadian Pacific Railway Company—or the "C. P. R.," as it is usually termed,—and as I hope to show in the following pages.

The projectors of this Line had to face at the outset a truly colossal undertaking. A railway from ocean to ocean had long existed in the minds of a few Canadians,

which, soon after the confederation of the Provinces, became a political necessity, and hence, the government conceived the idea of helping to carry out this scheme, the leading features of which have already been given in Chapter III.

In Eastern Canada, the permanent way of this line had few serious obstacles to overcome, as the country is easy to traverse, with, however, numerous flinty rock-cuttings to carve, and lakes and lakelets to thread, and rivers to follow or to cross on the road to Winnipeg. For the next thousand miles, up to the gates of the Rockies, the line has chiefly a flat and undulating prairie to traverse, which eventually lands us at Calgary. Starting from this point, with the Rockies 62 miles distant, though apparently near at hand, we head away to a new world. The ranching country is rapidly left behind as we approach "The Gap," where we pass at once between two lofty walls of rock which form the gateway to a transformation scene as exquisitely beautiful as the mind can conceive or the eye rest upon.

Most of the innumerable peaks we shall have around us for the next 500 miles range from 8,000 to about 12,000 feet in height, and have frequently been described by enthusiastic writers. Amongst them may be mentioned the late Dr. John Watson, who said, after a recent tour through Canada, "As we passed through the Selkirks and Rockies, so marvellous are the works of nature in this region for grandeur and beauty, that my wife and I have both agreed that nothing we had seen in Switzerland could be for one moment compared with what awaits the traveller between Vancouver and Calgary on the Canadian Pacific Railway."

Mr. Edward Whymper also, who, with a life-time spent in scaling the heights of Switzerland, the Andes, and the

Himalayas, etc., declared the "Canadian Rockies equal to fifty or sixty Switzerlands rolled into one." With these statements in view, I do not think that my own remarks will be considered exaggerated.

Soon after we passed the Gap the observation car gave us full control of both sides of the line throughout the country. After stopping at *Banff* for three days to survey the lovely district, I started early on a glorious summer morning with a very long daylight run before me, and as we rolled along everyone was intently watching the ever-changing aspects of what may well be termed the "Rockies." We left in the rear a sea of mountains, and had another in front of us—sometimes of the most extraordinary formation and awe-inspiring magnificence—and shortly afterwards arrived at *Laggan*, close to which are *Lake Louise* and the *Lakes in the Clouds*. Pursuing our course, we reached the railway summit, or "Great Divide." where a visible rivulet descending the ridge separates into two streams, one of which flows in increasing volume towards the Atlantic, and the other, similarly, towards the Pacific Ocean.

Passing onwards we enter the sublime gorge of the Kicking Horse Cañon, where, about 900 feet almost perpendicularly below us, is the Kicking Horse River. Not only does the decline we are now entering upon fall as much as 1,246 feet in ten miles, but the railway itself, as in many other places, runs upon a mere shelf cut out of a giant mountain side. The danger, however, is more apparent than real, as the Canadian Pacific Railway Company most rigorously guards this, and all other similar spots, in various ways as will be described later on. As we went down the Cañon, nothing could have exceeded the tender care bestowed upon us all by the

engine driver and brakesmen. We moved very slowly, *very* cautiously, stiffly rolling, and occasionally stopping, until at last we reached Field, where the gorge and river spread out, all ready for a good breakfast.

Crossing immediately afterwards the frontier of *Alberta*, we entered the unique and rich Province of *British Columbia*, or "B. C." as it is usually termed, having an area of 383,000 square miles, which makes it the largest province of a country which is fully double the size of all Europe, excluding Russia. From this point we rapidly rolled into the presence of the mighty Selkirk Range, where some of the most difficult railway engineering in the world is to be found, and between which and the Rockies rolls the Columbia river, which even here is navigable for 100 miles upwards by steamers.

After leaving Field we had another severely grand cañon to traverse, and with the Kicking Horse River still beside us, we reached Golden, a mining town on the bank of the Columbia. Amongst those who charmingly gave me much information about the country was one of Cook's officials. He said he had been all over the globe, and had seen loftier mountains than those we were approaching, but had never witnessed anywhere such beautiful atmospheric changes as those which pervade the Selkirks, which we are now about to enter—changes, too, which have greatly influenced the engineers in their work.

The usual custom in planning a railway for a mountain region is to take it along as many of the valleys and river courses as possible, because it is constructively less expensive than if it had long tunnels and cuttings and embankments to traverse. Now, however, we enter upon a change of principle, which has been very beneficially adopted for commercial reasons. As the Columbia begins

to make a long U-shaped "Big Bend" to Revelstoke—a distance of 150 miles—the Canadian Pacific Railway might have followed its course as usual. Instead of this, however, it *directly* crossed the mountains, a distance of only 68 miles to the same point—a crossing of stupendous magnitude and prodigious difficulties, to all of which the surveyors and constructors of the line were greatly exposed, the chief object being to reduce the cost of maintaining it in good order, and also to greatly diminish the distance to Vancouver.

Continuing our journey from Golden along the bank of the Columbia for 29 miles, we enter the Selkirks by the mouth of the Beaver river at a point where its torrent, surging through a deep and narrow gorge, is crossed by the "Devil's Bridge"—a tree so thrown across the stream that only a squirrel would dare to tread it. These mountains have had an extremely rough time of it, as their strangely cleft and torn, glacier scarred, and cascade gullied sides clearly indicate. We crossed many of these steel bridged chasms on the road to the summit, to which the line not only ascends from Beaver mouth by an incline of 22 miles in length, and 1,800 feet vertical rise, but is actually notched into the steep mountain sides for the greater part of that distance, the river gleaming like a silver thread far below us. To carry this line across such a country was certainly a triumph of engineering skill, especially when we consider the peculiar system of construction, which has been splendidly carried out.

Ordinary tunnels were almost entirely avoided, but an overwhelming danger from avalanches was ever present, which, but for the application of *snow sheds*, would have caused the line to pass through many costly excavations, or to have been abandoned altogether. As there are no snow

sheds in the Rockies, it may be stated that atmospheric influences existing in the Selkirks alone have produced an extraordinarily heavy fall of snow which, during the winter, has freqnently reached 35 feet in depth, but which, in 1898 to 1899, was as much as 44 feet. Sometimes snow will fall continuously for three weeks, thus creating many slides. The warm "Chinook" winds from the Pacific, and the winter rains, followed at times by severe frost, make the snow extremely heavy, and avalanches of this nature, almost as hard as ice, irresistibly come down the mountain sides, charged with trees and rocks, and thus constitute a grave source of danger if unprovided for.

Cutting a series of tunnels would not only have been a very expensive but a very unnecessary operation. The Canadian Pacific Railway Company, moreover, wished to make these mountains one of the show places of the world, and, with all this in view, their engineers planned and executed those wonderful sheds which have so admirably overcome the difficulty. Some idea of the extent and nature of the snow slides just mentioned may be gathered from the fact that they have sometimes been known to contain about 200,000 tons of ice, snow, rocks, and trees, mingled together in the most extraordinary fashion. When, too, it is considered that their first movement may begin on the top of a steep mountain, from 4,000 to 5,000 feet above the railway, their irresistible momentum and great speed, sometimes creating severe local cyclones, the unique grandeur of the scene may prove fascinating to those who view it in safety.

The snow sheds, or *timber* tunnels, which are exposed to such terrific treatment, usually consist of a very massive 12 in. square cedar framework, fitted at the back into the mountain side for protection, the front being openly planked

to allow good ventilation and light, and also views of the scenery which would not otherwise be visible. The roof, however, of immense strength, takes the slope of the mountain in such a manner as to let even the heaviest avalanches glide over it and, with the noise of thunder, fall into the valley below. As a protection from fire, these sheds, although several miles in total length, are built in short sections, with sufficient "firebreak" and avalanche guarded spaces between each of them. They are also very carefully watched by the local line hands, who keep everything in the best working order.

On the road to the summit we pass through a wondrous cutting of nature's handy work. Immediately on one side of the line the awful precipice of Mount Macdonald towers fully 5,000 feet in almost perpendicular height above the rails, Mount Tupper similarly rising on the other side, thus producing a scene of gigantic cliff formation which overawes one by a sense of immensity and mighty grandeur. These two matchless mountains were once apparently united, but ages ago, some terrible convulsion of the earth split them asunder, leaving just room for the railway to pass; thus forming a splendid example of the manner in which nature sometimes aids the engineer at otherwise impossible points.

Leaving behind us "Sir Donald"—otherwise "Lord Strathcona"—of 11,000 feet, and a sea of grand peaks, also the "Great Glacier"—nine miles in length, and 3,000 to 4,000 feet in depth in the middle—we reach the famous "Loops," where the line, having to fall 600 feet in two miles of direct distance, traverses six miles of the most extraordinary double curves and bends, which eventually reduce the natural slope of the rails from 1 in 17½ to 1 in 52½, thus forming a highly successful piece of railway construction.

Proceeding onwards, we at last reach Revelstoke, on the banks of the Columbia, now much enlarged. Here I branched off the main line for the mining regions of Kootenay by rail, and then by steamer for 160 miles down the Arrow Lakes to Robson, and by rail again to the gold mining mountain city of Rossland. As the line here falls 1,000 feet in only seven miles, it passes over a series of inclines and curves and zigzags of wonderful nature indeed to those only accustomed to our insular style of engineering. At Trail, for example, for want of space, the engine merely pulled and pushed our train over several zigzag slopes without any curves whatever, until we again reached the bank of the Columbia, which, in lordly style, rolls across the International boundary line for hundreds of miles to the Pacific. Even in this less rugged district we have the Kaslo and Sandon Railway skirting for some distance the edge of a precipice whose sheer depth is 1,050 feet.

On returning to Revelstoke we again crossed the great river into the Gold Range, and amidst continuously magnificent mountain, lake, and river verging for the next 250 miles, reached the sublime Cañon of the Fraser River, upon which travellers may well bestow such phrases as "startling," "matchless," "awful," "enthralling," and so on. It may give some idea of the stupendous constructive difficulties of this region to learn that, although the line from Winnipeg to Vancouver occupied only five instead of ten years in building, owing to the skill and energy displayed, the 23 miles through this cañon required two and a half years of severe labour to complete. For want of an easier course, the line was compelled to follow the river, with lofty mountains rising abruptly from the water's edge. The engineers, therefore, had a lively time of it between rock drilling and blasting through hard mountain spurs on

the one hand, and building stone embankments on the other. At other times, they had the pleasing variety of cutting and quarrying ledges to carry the railway on the face of prodigious natural walls.

Just fancy yourself in a train, rolling along at from 100 to 200 feet above the water, with gully and chasm bridges, short spur tunnellings, etc., in profusion. All the time, too, skirting the edges of eddies, narrows, surging rapids and whirlpools, on the bank of a river which has risen as much as 70 feet in time of flood!

After many miles of similar and consequently slow and very cautious travelling, we reached "Hell Gate," where the passage of the water amongst opposing rocks was truly wonderful. During this part of the trip I had the great advantage of meeting Mr. J. T. Moore, of Toronto, who was kind enough to tell me what he knew of this region, with an enthusiasm, too, I shall ever delightfully remember. Rolling onwards, we reached the suspension bridge at Spuzzum, adjoining the old Cariboo Road, by means of which miners and their stores were carried by wagons into the interior of British Columbia. Here I had a splendid view of precipice engineering, which has been much used for carrylng roads and timber built water channels or "flumes" in mountainous regions for motive power, irrigation, or town supply purposes. Near the Spuzzum bridge there is a sheer precipice just bordering the river, on the face of which men had been slung by ropes, as in many other similar places, to cut apertures in the rock for the fixing of timber cantilever beams to support the pathway. As this once useful structure was no longer required, it was allowed to rot and picturesquely tell its own story.

And now, as we stop for a few moments at Yale, at the foot of the Cañon, we feel that all the savage gorges, and

mountain climbing, and descending, and chasm verging and spanning; the giant *in*clines and *de*clines, and wonderful loops and other marvels of the country are past. We cross some fine tributaries of the Fraser, and soon afterwards reach Hope, an important mining and trading town. The cañon has now greatly widened out, and, passing the entrance of the branch line to New Westminster, we enter a rich and beautiful plain, with Mount Baker, of 14,000 feet, 60 miles distant, and with the Coast Range mountains receding on both sides of the railway.

The engine-driver opens his steam valve to the full, and now, flying along the line for the next 85 miles, we "strike" Burrard Inlet. The delightful breezes of my old friend—the Pacific—are on us, and at last, on a hot and brilliant day, amidst the exquisitely clear air which everywhere pervades Canada, and greatly benefits photography, our train entered Vancouver terminus at 1 p.m., dead to the minute, after a run from Montreal of about 3,000 miles.

With the object of noting how the line is protected at critical points, I had special permission to traverse the Rockies on the cowcatcher of a locomotive. Again stopping at Golden, on the return trip, and with no time for ceremony, I asked the fireman for a piece of cotton waste, with which I cleaned my portion of the buffer-beam. The passengers gazed at me as if I were a lunatic out for a holiday, and the driver informed me that "no one was allowed on *his* engine." "*Indeed!*" I said, with lurking humour. "Would you kindly read *that letter*." He did so, and on returning it said: "All right sir."

After leaving the station on one of the loveliest of days, the scene soon changed to one of fascinating grandeur as we rolled towards Field—where Mount Stephen's sublime and rugged head rose 8,000 feet above the line—and again

entered the Kicking Horse Cañon, which closed in upon us as we passed up its long and steep incline. So heavy was our train that we required one engine behind to push, and two in front to strenuously pull. Seated on the foremost cowcatcher, I salaamed the line hands in governor-general style as I passed them in these lonely fastnesses, and was delightedly saluted by them in return, as I noted the careful manner in which the safety of the trains was assured, every quarter of a mile being under the supervision of men who were ever ready to stop any approaching train if danger threatened. At last we reached the top of the incline, but no sooner did we put on full speed while coming *down* this side of the Rockies, than I had to cling with cat-like tenacity to a naked buffer beam or—these lines might never have been written.

Having briefly sketched the *physical* features of the country over which one of the greatest and most successful railways in the world has been carried, let me now endeavour to show how its initial surveys and subsequent construction were carried out. Throughout a large portion of the Dominion both of these operations were of a simple nature, the cuttings, embankments, bridges, etc., being chiefly of the usual and well-known description. When, however, we come to the morasses and lakes, upon which a vast amount of very troublesome *piling* work was bestowed, we find out a few of the great differences that exist between the engineering practice of the British Isles and trans-atlantic countries.

In the localities just named the surveying operations were, as a rule, very similar to our own, and yet there were painful surprises in store for the engineers which nothing could have averted. Take, for instance, the system of piling, upon which the very existence of some of the

famous cities of the world, and many of the greatest engineering works have depended. Generally speaking, it is a simple and reliable process, but in the lakes and bogs of Canada it has frequently proved a most perplexing one. Partly because some of the best formulæ have been so misleading that the constructors had nothing to trust to but their own discoveries in this science. On the route of the Canadian Pacific Railway, between Fort William and Winnipeg, many trestle bridges were built through lakes, the bottom of which consisted of soft, peaty material from *fifty* to *seventy* feet in depth, and resting on a bed of some other foundation which sank when the structure was completed, thus causing extensive additional work, and occasionally serious deviation of the line.

The numerous morasses that were encountered sometimes proved quite as objectionable as the lakes, but here, George Stephenson's method of crossing Chat Moss gave useful hints. As good examples of piling, on a colossal scale, it may be mentioned that, to save a very long double bend, a railway is carried on a trestle bridge for 25 miles across Salt Lake, in Utah; and another railway is now being built through the sea for 100 miles to connect Key West, in Florida, with the United States on one side, and Cuba on the other.

Although the Canadian Pacific Railway traverses 1,000 miles of prairie, it has many interesting features, one of which is a simplicity of construction which enabled the line to be laid at the rate of three, to even six miles a day, when the surface of the ground allowed of it—a wonderful contrast to some of the other places mentioned, where progress was greatly retarded.

Passing over the troublesome work of the engineers already mentioned in Central Canada, where glacial action

has produced endless lakes and lakelets, and transformed the once immense Lake Agassiz into the fertile plains of Manitoba, etc. We now come to their still greater and more harassing labours in a territory which had to be explored frequently at the risk of life and limb, and very often under the most unfavourable conditions.

From two handsome volumes recently published by the Department of the Interior at Ottawa, and entitled *The Selkirk Range*, by Mr. A. O. Wheeler, F.R.G.S., we learn much concerning the physical and many other interesting peculiarities of these mountains, and of the extraordinary efforts of the early surveyors of the Canadian Pacific Railway during their endeavours to find the best way across them, much of which is as fascinating as a romance. These books are splendidly illustrated with maps and plans, and portraits of distinguished people engaged in the enterprise, and also many photo. views which only very clear air could produce. The Rockies and the Gold Range, however, have their own stories to tell in various ways, some of which have already been given by other people.

During my stay in Montreal I made many charming friends, from whom I obtained numerous tit-bits of information regarding Canada, and especially from the chief officials of the Canadian Pacific Railway Company. *Sir Thomas Shaughnessy*, for instance, now the President, told me, with quiet humour, that while Sir William Van Horne and his engineer-in-chief were exploring one of the western rivers in a boat piloted by an Indian, they were much annoyed by his irregular steering.

"You don't seem to know the navigation of this place," said the engineer, somewhat testily. No answer.

"I wish you would get on faster, and not waste our valuable time." Again no answer.

"May I ask if anyone has been down this river before?"

"Yes sir," at last replied the Indian, "but—*they're there still!*"

Sir Thomas also told me some curious facts about the mountain regions which have never been printed.

Sir William Van Horne, who commercially and most successfully "bossed the show" from early days until now, even in his retirement, received me most cordially, and gave me many valuable hints about the country, and also the course to steer most advantageously through it. While *Mr. D. MacNicol*—now Vice-President—most kindly supplied me with much general and topographical information. *Mr. Peterson*, too, the engineer-in-chief, gave me full details regarding *his* department of practical science.

Besides this, I was generously presented by a friend with a packet of letters to leading people from Quebec to Victoria, B.C., in which, also, the Governor General handsomely offerred to aid me.

Up to the time I reached the Kicking Horse Cañon there did not seem to be any special difficulties for the engineers to overcome. Here, however, they had much to perplex and baffle them, though only temporarily. One of the early explorers, in 1858, was *Dr. Hector*, who, while passing through this region was severely kicked by one of his pack-horses, hence the above name. In 1860, *Captain Palliser*, another talented surveyor, declared that all hopes of carrying a line through British Columbia must be abandoned, as the Gold Range was impassable. *Mr. Moberly*, the Government engineer, however, after carefully surveying the same district in 1872, and coming to a similar conclusion, had his attention arrested one day by the flight of an eagle through the air. Upon instinctively following the

course thus opportunely flashed upon him, he discovered at last, what has since been termed, the "Eagle Pass" and "Eagle River," which solved the difficulty.

In the Selkirks, the surveyors had every kind of experience, from swinging exploringly on a rope over a giant precipice or otherwise inaccessible mountain side; daintily treading a tree bridge; crossing a vast chasm, or a turbulent river, by means of a rope stretched high above either of them; traversing ledges of rock or glaciers, only fitted for a goat; living in dug-outs for months together, amidst intense cold, and hundreds of miles from civilisation; climbing to the tops of colossal trees to take observations, and perhaps traversing *snow bridges*. These are formed by avalanches so blocking a river that the rising flood, at the back of the dam thus formed, forces a passage through it in the centre, the heat of the summer sun melting the rest into arch form.

Constructively, there is very much to learn by the study of Trans-Atlantic engineering. Great undertakings, such as the Manchester Ship Canal, and vast earthworks of all kinds, are everywhere splendidly executed by means of the Steam Navvy or Mechanical Excavator. In the regions just described, however, something else must be used more adaptable to the locality, and here, the magnificent water power resources of British Columbia prove very handy. Owing to the greatly increased traffic upon the Canadian Pacific Railway, many of their lines have been, and are still being, reconstructed. That is, heavier rails are being laid, and deviations made when advisable. Steel bridges are taking the place of the former timber ones. Gullies are being filled up, and the once popular trestle viaducts dispensed with, etc., etc.

This filling in work is rapidly performed by means of hydraulic "Giants," or "Monitors," the motive power of

which is very high pressure water, due, perhaps, to some hundreds of feet of vertical head. These monitors are similar in action to the hand gear of the fireman, and so mechanically arranged as to be capable of easy transport and adjustment to suit the work in hand. One, for instance, used by the Canadian Pacific Railway, had a supply pipe fifteen inches diameter, extending 584 feet up a mountain side, the former of which had a working nozzle of five inches bore, through which water was delivered with such terrific force as to disrupt walls of rock, disperse boulders, and dislocate, disintegrate, dislodge, and finally direct every kind of strata to the required spot in the chasm to be filled up. The pipes, up to, say, six feet bore, are usually made on the spot, either from steel plates, or of timber strongly bound together by adjustable steel hoops, in tub fashion.

Sometimes the water channels for irrigation, mining and other purposes, are of open trough formation, and carried partially along the face of precipices, or in any other suitable manner, one of which, recently built in India, is 8′ 6″ square inside. In this respect, Sir Hugh Myddelton gave us a splendid example, when, 300 years ago, he similarly built, at his own expense, a trough 39 miles in length, and ten feet wide by five feet deep, by which, under the name of *New River*, he generously supplied the 150,000 population of London with pure water.

If the pipes are made of steel, the plates are curved and punched by special machines, and riveted by hydraulic hand gear. In all cases, however, where such work has to be performed in mountain regions, the whole of the materials and also the machinery for operating upon them, must have each piece kept light enough to be carried on horse back.

As I rolled along the Canadian Pacific Railway, I much admired the efficient and inexpensive manner in which it

was originally built to *create* a traffic through a wilderness for thousands of miles. So effectively has this been done; so enormously has Canada become developed in trade, manufactures, population, and as a happy hunting ground for multitudes of summer visitors, that not only have the prodigious improvements already mentioned been made in the old lines, but wide-spread extensions have been, and are still being made, by which the steel roads of the Company now exceed 13,000 miles in total length.

Besides this, the *Grand Trunk Pacific*, and the *Canadian Northern* Companies are rapidly constructing trans-continental and other lines of their own, of many thousands of miles in length, to meet the requirements of the times.

All of these facts tend to show the wisdom of the early promoters of the Canadian Pacific Railway, who, amidst serious political, commercial, and constructive difficulties, carried their line through to Vancouver, and thus opened out a new path for the world at large, and for those, too, who thus wish to travel westward to the Far East. Having traversed a large portion of Canada by this line, I have, of course, spoken of it from *practical* experience, but perhaps at a future time, I shall have the pleasure of similarly treating the others named, when the opportunity presents itself.

The most colossal and wonderful works in engineering are now chiefly to be found abroad. Fancy taking a railway across Salt Lake, 90 miles long by 40 broad; or 100 miles through the sea; or to an altitude of 15,000 feet over the Andes; or through a channel tunnel under the Straits of Dover; or building a lake steamer thousands of feet up in the Coidilleras; or draining the Zuyder Zee, and so on. From these, and many other similar illustrations, we have forcibly brought home to us the now overwhelming

resources of the engineer, for whom nothing seems too great, nothing too difficult. Not even in the proposed deepening of the navigable channels of the Mississippi and Missouri, and other rivers, and the formation of numerous improved and deep water canals throughout the United States and Canada, at a projected cost of some hundreds of millions of dollars. These contemplated works have been found necessary, as the present enormous railway extensions in both countries are unable to keep pace with their rapidly developing trade.

A good example of this is to be found in the various causes which have originated the magnificent Montreal, Ottawa, and Georgian Bay Ship Canal enterprise, which, at an estimated cost of £20,000,000, promises to be a valuable addition to the transportation facilities of Canada.

It should be a charming occupation for the mere tourist to visit such works as those mentioned in this chapter, with open eyes and open mind for everything that rises to view, in scenery, or in personal friendships when on travel, or for the mighty forces which built up, and cleft, and carved the mountains, and scooped the river beds. The same occupation, however, is *invaluable* to the embryo "Eminent," who hopes some day to become a walking encyclopedia of his profession, or at least the possessor of more generally useful practical knowledge than he could otherwise obtain in the field of Railway Engineering, to which this volume has been devoted.

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